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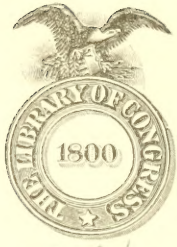

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DEPARTMENT OF COMMERCE AND LABOR

BUREAU OF FISHERIES

GEORGE M. BOWERS, Commissioner

THE MUSSEL FAUNA OF THE MAUMEE RIVER

Bureau of Fisheries Document No. 757

WASHINGTON
GOVERNMENT PRINTING OFFICE
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THE MUSSEL FAUNA OF THE MAUMEE RIVER

By H. Walton Clark and Charles B. Wilson

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THE MUSSEL FAUNA OF THE MAUMEE RIVER.

By Charles B. Wilson and H. Walton Clark.

INTRODUCTION.

This report embodies the results of an investigation of the mussel fauna of the Maumee River, carried on under the auspices of the United States Bureau of Fisheries during the summer of 1908, and it represents a part of the series of investigations undertaken by that Bureau looking toward means of continuing the supply of mussel shells. Upon this supply, which had begun to show signs of serious depletion, depends one of the important industries of the country, the pearl-button industry of the Mississippi Valley.

The scope of the inquiry embraced whatever appeared to be closely related to mussel life, such as the history and character of the river and its present mussel supply as regards abundance, quality, and species. It was desirable also to ascertain where good breeding stock might be obtained, the location, character, and condition of mussel beds, and circumstances in which different species appeared to thrive. Such features of general life history as food, habits, time and manner of spawning, enemies, and parasites were also noted whenever opportunity offered.

In the choice of the area to be studied, the features to be emphasized during the investigation, and similar details we have had the direction and advice of Dr. Barton W. Evermann, Chief of the Division of Scientific Inquiry of the Bureau of Fisheries. His counsel has been of great assistance in the preparation of this report.

In addition to the Maumee River, the upper part of the Wabash Basin was also investigated, in order that the two basins might be compared where they are close together. This latter part of the work also yielded many interesting results, especially in the spawning habits of mussels and the life history of parasites. The results of the Wabash investigation are frequently referred to briefly where they carry on lines left incomplete by the Maumee studies.

The authors had as an associate in the work Mr. Donald M. Earll, of Washington, D. C., to whom is due much credit for the results.

During the Maumee investigations, not only the main river, but also the two streams which unite to form it, the St. Joseph and St. Marys, were examined for the last few miles of their course, and the other principal affluents, the Tiffin and the Auglaize, were likewise investigated for a short distance above where they join the Maumee. Other bodies of water flowing into the Maumee or closely related to its basin, such as the feeder canal at Fort Wayne and its reservoir, and Spy Run, a small tributary to the St. Marys not far above its mouth, were studied. Below Defiance, Ohio, the Miami and Erie Canal runs parallel with the river, and was followed to avoid the riffles and difficulties of navigation to be encountered in the main stream. It offered a favorable subject of research in itself and the Maumee could readily be examined from time to time, as that river was never any great distance away.

During the trip to the United States fish hatchery at Put-in Bay, Ohio, opportunity was taken to examine the mussel fauna of that region. This gave data for inference as to which species had probably ascended the Maumee from Lake Erie and which had entered more recently from the Wabash system. It also furnished a basis for comparison between the river and the lake mussels as regards size, etc.

The authors are about equally responsible for the work. To Mr. Clark belongs the credit for the final determination of the mussel species, all of the observations on the food of mussels, and most of those upon the parasites. Dr. Wilson supervised the work and has furnished the geological and geographical distribution and most of the notes upon the various stations.

GEOLOGY AND GEOGRAPHY OF THE MAUMEE AND UPPER WABASH BASINS.

Although the Maumee River flows into Lake Erie and is therefore a part of the great St. Lawrence system, while the Wabash flows into the Ohio and thence to the Mississippi, the basins of the two rivers have been so intimately connected in their geological history and topographical features, as well as by the artificial connections established during the existence of the Wabash and Erie Canal, that they are practically one. Even at the present day the headwaters of the Little Wabash River approach within 3 miles of the St. Marys River and still nearer to small affluents of that stream, and when the white settlers first came to Fort Wayne they found this point an important portage for the native Indian tribes. There is no perceptible divide between the two basins, and a large open country ditch still unites them through an old flat lake plain known locally

as "the prairie." A careful examination of this ditch revealed no mussels at all, and it is not likely they could live in the mucky bottom, though it is possible that glochidia might be carried through the stream by migrating fishes.

During the glacial period the entire region was buried under the ice, and every form of molluscan life was exterminated. At the melting of the ice sheet great bodies of water were formed which could find no outlet to the eastward on account of the still unmelted ice, and therefore all the water was compelled to drain toward the south and west into the Ohio and Mississippi Valleys. The old channels can still be traced and are represented on the geological maps of the region. The geologists tell us that at first there were two of these lakes entirely separated from each other. The easternmost one, Lake Maumee, covered the present basin of the Maumee River and the upper part of the Wabash Basin and was 100 feet higher than Lake Chicago, which lay to the west. Lake Maumee drained through the Maumee and Wabash Valleys into the Ohio, while Lake Chicago found an outlet along the Des Plaines and Illinois River Valleys.

The restocking of the region with mussels must have been effected by migration through these respective outlets. At this period several of the more hardy species came up through the Wabash Basin into Lake Maumee, as is attested by the finding of their shells among the fossils of the period. At the beginning, therefore, the Maumee Basin was restocked with Ohio Valley species of mussels, which came to it by way of the Wabash River.[a]

After the ice had retreated far enough northward to reveal the surface features of the region under discussion, it exposed the valley of an ancient preglacial river, sometimes called the Huronian River, and now known as the Saginaw-Grand Valley. This river valley runs east and west across the southern part of the State of Michigan and became a channel connecting the two lakes just mentioned. The opening of this channel gradually lowered the water in Lake Maumee to the level of that in Lake Chicago. A series of terminal moraines which had formed along the southern margin of Lake Maumee were enabled by this lowering of the water to assert themselves and close the Wabash outlet. These moraines are known to geologists as the Mississinewa Moraine, to the south and west of which lies the Mississinewa River, the Salamonie Moraine, to the north and east of the Salamonie River, the Wabash Moraine to the north and east of the main branch of the Wabash River, the St. Joseph-St. Marys Moraine to the east of those two rivers, both of which drained originally into the Wabash, and the Defiance Moraine

[a] For an interesting discussion of this subject, see Simpson, American Naturalist, vol. xxx, p. 379–384.

to the east of the Tiffin and Auglaize Rivers. The former drainage of the St. Joseph and St. Marys Rivers through the Wabash is indicated by the peculiar turn they make at Fort Wayne, where they unite to form the Maumee. This sudden change, of course, is so striking a feature that it has excited comment by almost everyone who has considered the topography of the region. The situation is well expressed by Mr. Simpson who says:

> The St. Josephs, St. Marys, and Auglaize Rivers, tributaries of the Maumee, flow in the direction of the Wabash; the two former join at Fort Wayne and flow partly backward as the Maumee, the whole looking like a tree with its branches broken down and hanging against its trunk.[a]

From the time of the closing up of the Wabash outlet until the St. Lawrence was reopened, the only outlet for Lake Maumee was through the Huronian channel into Lake Chicago, and thence into the Des Plaines and Illinois Rivers. All the mussels, therefore, which took part in restocking Lake Maumee during this period belonged to the Illinois River fauna and entered the lake by this roundabout channel. The Unionidæ are essentially inhabitants of shallow water and would have spread along the margin of these glacial lakes. As the level of the lakes was gradually lowered and the present system of drainage was established, the mussels naturally followed the retreating waters, and thus finally found their way into the river beds where they now live.

This account of the origin of the present mussel fauna in the Maumee and upper Wabash Basins is adapted from several geological reports of the States of Indiana and Michigan and from an excellent paper on the "Distribution of the Unionidæ in Michigan" by Bryant Walker.[b]

From the foregoing account of the manner in which the stocking of the Maumee Basin took place, it would naturally be inferred that in the lists of species of mussels obtained at the various stations on the Maumee and Wabash Rivers by the party, there should be more than the usual amount of similarity between those from the headwaters of the two rivers, and this similarity should decrease the farther down the respective rivers the comparison is made. Such we find to be actually the case. (See p. 38.)

But there is another factor which may at least claim a share of the credit for the correspondence in species.

The Wabash and Erie Canal was in active operation between these two rivers for nearly half of the last century. Starting at Toledo, Ohio, it ran along the bank of the Maumee for the entire length of that river to Fort Wayne. There it crossed the narrow strip of country between the headwaters of the two rivers, ran along

[a] American Naturalist, loc. cit.

[b] Author's separate of a paper read before the Michigan Academy of Science, March, 1899.

the edge of the old lake plain or "prairie," near the Indian portage and at no great distance from the Little Wabash, struck the main Wabash below Huntington, Ind., and then followed the latter river down to the Ohio. This canal was fed from the two rivers and opened into them at various points along its course.

There was thus established a channel of communication which, during its half century of existence, must have resulted in the exchange of many species of mussels, as well as other portions of the fauna of the two rivers.

Such a canal furnishes an excellent breeding ground for mussels, as is well shown in the case of the old feeder canal at Fort Wayne (p. 19) and the Miami and Erie Canal still in existence between Defiance and Toledo (p. 34).

This artificial opportunity for interchange of species, occurring so recently, must have greatly supplemented the original similarity due to the former identity of the drainage basins. It would also go far toward destroying any local peculiarities that might have developed since the two basins were separated.

The Maumee Basin is situated in the northeastern part of Indiana and the northwestern part of Ohio, and covers an area of 6,500 square miles. There are no large hills in or around it, it being a flat glacial plain, covered with moraines and low ridges. The basin abounds in clay and solid subsoil, so that the river is rather muddy most of the time. The water is also quite hard, furnishing an abundance of lime to the mussels for their shells. In the upper part of the river, as far down as Defiance, Ohio, there is considerable sand and gravel bottom, but below Defiance a good deal of the bottom is solid bedrock. As already stated, the Maumee is a very young river in point of geological time, yet, next to the Detroit River, it is the largest tributary of Lake Erie and is one of the largest rivers within the State of Ohio. The Maumee is formed by the junction of the St. Joseph and St. Marys Rivers, just beneath the Columbia Street Bridge in Fort Wayne, and flows northeast to Lake Erie at Toledo, Ohio. From origin to mouth is about 100 miles in a straight line, but as a result of the angular or crescentic form of the glacial moraines which separate the Maumee from the Wabash Basin, the river winds greatly, especially that portion of it above Defiance, and thus adds fully 50 miles to its length.

As might be expected, the current is not very swift except during high floods, since the river falls but 164 feet in its entire course, or a trifle over a foot a mile, and much of this is accumulated in a series of riffles at Defiance and Grand Rapids. Elsewhere the river is made up of long, sluggish stretches, alternating with short riffles of varying lengths, and it is in the vicinity of the latter that most of the mussels are found.

Through the removal of most of the forests which once covered the area about its headwaters, the current and depth of water are not so constant as they once were, but the river rises and falls more suddenly, and is usually considerably more turbid or muddy than formerly. The height and activity of the river in times of flood are strikingly manifested by the tangled piles of drifted logs and brush up on the flood plain high above the normal surface of the river.

This change in the steadiness of flow of the river, with the accompaniment of a more shifting bottom, has probably had considerable effect on the mussel life of the stream.

BIOLOGY OF THE MAUMEE RIVER.

Through the abandonment of the Wabash and Erie Canal, which took place nearly 30 years ago, and the draining and gradual drying up of the old lake plain or prairie, the Maumee River has become isolated from the Wabash, so that there has been no transference of species for some time.

In the course of our work our attention was devoted chiefly to the mussel fauna. The general features of the river and its inhabitants, both plant and animal, undoubtedly have many important relations to the mussels, but, on account of the limited amount of time at our disposal and the impracticability of carrying on several lines of work at once, only such features were noted as appeared to have some evident bearing on mussel life. In the St. Marys River and about the region of Fort Wayne, where conditions were favorable, the river was more thoroughly explored than elsewhere, the flora and fauna were noted, and the stomach contents and parasites of the mussels were examined. All along the way stomach contents and parasites were preserved for future study.

A valuable addition to our knowledge of the biology of the Maumee Basin has been furnished by a report of the investigations made by Philip H. Kirsch during the summer of 1893 and published in the Bulletin of the United States Fish Commission (vol. XIV, for 1894). This report refers to an abundance of algæ in various places, and furnishes a list of 87 species of fishes, 3 species of mussels in the Maumee, 4 species of crawfishes, 7 of batrachians, 6 of snakes, and 6 of turtles. In this report the remark is made that mussels are common.[a] They are, however, only incidentally mentioned, so that

[a] The mussels obtained by Kirsch during these investigations were later turned over to Mr. C. T. Simpson for examination. In an interesting discussion concerning the "Mississippi Valley Unionidæ found in the St. Lawrence and Atlantic drainage areas," in the American Naturalist, vol. xxx, p. 379–384, Mr. Simpson remarks of these shells:

"This changing of characters" [a number of changes have just been discussed] "has been well illustrated in a lot of Unionidæ recently submitted for examination by Prof. B. W. Evermann, of the U. S. Fish Commission. * * * *Unio lutcolus* Lam., *U. subrostratus* Say, *U. circulus* Lea, *U. phascolus* Hild., *U. multiplicatus* Lea, *U. multiradiatus* Lea, and *Anodonta grandis* Say, are so dwarfed and stunted and changed in color as to be scarcely recognizable, while the same species from the Wabash from which these have no doubt all been derived, are as vigorous and finely developed as any in the Mississippi Valley."

Kirsch's report and the present one may be regarded as supplementary to each other.

The following general observations were made concerning the biology of the stream:

Among the aquatic plants, *Oscillatoria* was abundant in the St. Marys River and the upper portion of the Maumee down as far as Kern Reservation, 7 miles below Fort Wayne. In the St. Marys this plant was found floating in large blackish or blue-green bunches on the surface of the river;[a] farther down much of the floating *Oscillatoria* seemed recently washed in. Filamentous algæ, probably *Cladophora*, grew on the rocks in the bottom and occasionally on the shells of the mussels. Wild celery (*Vallisneria spiralis*) was abundant on the bottom of the St. Marys at Fort Wayne, but was not conspicuous farther down. The dense-flowered water willow (*Dianthera americana*) fringed the edges of the river and lower portions of the canal all along the way and was one of the plants most constantly seen. During the latter part of the cruise along the Miami and Erie Canal this plant was covered with large tangled clumps of dodder, so that the prospect either way along the canal was lined with great masses of yellow here and there. Algæ of many sorts grew in great abundance in the Maumee below the dam at Defiance. Portions of the canal from Napoleon, Ohio, to the locks below were covered with a dense scum of delicate little water fern, *Azolla caroliniana*. Along the lower stretches of the canal *Ceratophyllum* was abundant in stretches of quiet water. *Typha latifolia*, the narrow-leaved cat-tail, formed a dense hedgelike growth along the edge of the canal in places. The spatterdock, *Nymphæa advena*, was fairly common along the lower reaches of the canal and the white water lily, *Castalia odorata*, occasional. Duckweeds were common in the canal, but not noted in the river.

As to animal life, various species of protozoa were very abundant in one place in the St. Marys, as will be described later on. (See p. 13.) They were not noted farther down the river; however, there was little opportunity to examine carefully for them. No plankton was taken, but the material examined from the stomachs of mussels probably gives a fair notion of the nature of the smaller free plankton elements. Sponges and flatworms were rather common on rocks and shells the whole length of the river. In addition to the mussels, various mollusks such as *Pleurocera*, *Ancylus*, and *Sphærium* were common. Crawfishes were abundant everywhere in the river, but were not often noted in the canals. Aquatic insects and larvæ were not

[a] Further observations show that the presence of *Oscillatoria* and other minute organisms is a periodic phenomenon. They accumulate during periods of low, stagnant water but altogether disappear during periods of high water with rapid current.

especially abundant, except below the dam at Defiance. According to residents of the region along the river, fishing was in general rather poor, although in a few places, as several miles above Defiance and below Defiance Dam, angling was enthusiastically carried on by men wading out in the stream in high boots and casting. In the autumn of 1907 a good deal of angling was observed in the St. Joseph River just above its mouth, at Fort Wayne. The anglers there were catching a good number of the wall-eyed pike, or pike perch, *Stizostedion vitreum*, which they called "pickerel." We did not see many fishes in the water during most of the cruise, although at Fort Wayne, where we had opportunity to examine carefully, a number of species were observed, and all along the Maumee the small-mouthed black bass seemed fairly common. The darting fishes frequently struck the boat with resounding whacks and occasionally jumped over the boat or even over our heads as we sat in the boat. They frequently jumped against different members of the party and fell back into the water, and 6 examples, most of them quite large and fine, jumped into the boat and were captured. At one place, a little above Woodburn, Ind., we passed through a large school of basking gars.

Among aquatic birds and waders, kingfishers (*Ceryle alcyon*) were fairly common, green herons (*Ardea virescens*) and the great blue heron (*Ardea herodias*) were quite abundant, the former along shore or on branches of trees and the latter standing statuesquely on rocks in midstream and rising with a low level flight as we approached. We saw several small flocks of wood ducks (*Aix sponsa*) which seem to be summer residents. Sandpipers were common along shore and flocks of killdeer occasional on bars. On account of the northern latitude it is perhaps worthy of note that the song of the Carolina wren came to us frequently from the woodlands along the upper stretches of the river.

No aquatic mammals were seen, although occasional shell piles gave evidence of the presence of a few muskrats.

MUSSEL SURVEY.

HEADWATERS OF MAUMEE AND LITTLE WABASH BASINS.

The region in and around Fort Wayne is of peculiar interest, since it is the borderland between the two river basins, and also furnishes much evidence of the influence of the old Wabash and Erie Canal upon the mussel fauna. For this reason, considerable time was spent here before beginning the specific work upon the basins themselves. Most of the localities reported upon were worked over several times

in order that there might be a reasonable certainty that all the resident species had been found. A careful study was made of the species themselves and data collected as regards food, parasites, etc. The localities examined include the St. Marys and St. Joseph Rivers, Spy Run, a small tributary of St. Marys, and an old feeder canal and its reservoir which was formerly connected with the St. Joseph River.

The Aboit and Little Wabash Rivers, which belong to the Wabash system, were also examined. The stations at these localities are designated by letters, those on the main river by numbers. The relative abundance of the different species at each station is indicated by giving the number of examples obtained, or by remarks.

ST. MARYS RIVER AND SPY RUN.

In the St. Marys River the shells are scattered irregularly everywhere, so that along the bank a few dead shells may be found every now and then, or an occasional live mussel seen in the water. There are a few shell beds, all of small size, however, where conditions appear to have been exceptionally favorable for the development of molluscan life, and at such places the mussels are fairly abundant.

Station A. Above the Bluffton Road Bridge, at Fort Wayne.—The highest point at which the St. Marys River was examined was above the Bluffton Road Bridge, about 4 miles from the mouth of the river. At this place there were riffles and the remains of an old dam, and the point lies above the entrance of most of the sewage of the city. The water was shallow and the bottom covered with gravel, sand, or mud, according to the rapidity of the current. At the date examined (June 26) the water was quite turbid and nothing could be seen on the bottom. We had heard reports of a goodly number of shells there, but by wading about considerably we found only a few. The living mussels were hard to find, partly because of the stony bottom and partly because of their actual scarcity. A man fishing at the place was offering boys who were swimming near by 5 cents apiece for mussels, which he wished to use for bait, and it was noteworthy that although the boys were searching diligently the fisherman was not oversupplied. We found a fair number of dead shells on the shore, representing 18 species.

The little *Truncilla sulcata*, which seemed on the whole a rather rare shell, and of which during the entire summer's work we found only 1 live example (although scattered valves were occasionally found along the river bank), seemed unusually common here; we obtained 4 entire shells and 10 valves. None of the larger species of mussels were present in sufficient numbers to be of commercial value.

while all of the others were either too small or so discolored as to be unfit for use.

The river was followed from this point down to Swinney Park, a distance of about a mile and a half, but practically no shells were seen, and men wading in the river fishing for crawfishes with dip nets knew of none. From Swinney Park down to the riffles, soon to be discussed, the river had been examined fairly well during the previous year, and no shell beds of any importance had been found. Occasionally dead shells had been seen scattered along shore and in one place a few large *Lampsilis ligamentinus*, which had probably been killed by fishermen for bait.

Station B. Riffles, St. Marys River below the Van Buren Street Bridge.—The most important bed found in the St. Marys River was at the riffles, about an eighth of a mile below the Van Buren Street Bridge and across from the city waterworks pumping station.

The riffles are conveniently near the residence of Miss Elizabeth J. Bowman, at 719 Michael Avenue, who very kindly gave us the use of her house and grounds as a laboratory headquarters for the work in and around Fort Wayne. Being so favorably situated, this station was repeatedly visited and the mussels obtained were carefully examined for food, parasites forming pearls, etc.

As the opportunity for doing laboratory work is rather rare in moving field parties, and as it was supposed that this mussel bed would be fairly typical of others we would encounter but would not have opportunity to study fully, this bed was investigated and the observations noted in considerable detail.

The stretch of river above the mussel bed was about 8 feet deep at its greatest depth and 60 or 80 feet wide, with a sandy bottom, and was used by the boys as a swimming-hole. A large quantity of sand for building purposes had been hauled out of the river at this place and screened some little distance from the river bank. Among the screenings was a fair number of mussel shells of different species and shells of *Pleurocera* and *Sphærium*. The species of mussels represented by the shells among the screenings were *Quadrula rubiginosa*, *Q. undulata*, *Pleurobema clava*, *Unio gibbosus*, *Symphynota complanata*, *Anodonta grandis*, *Lampsilis gracilis*, *L. rectus*, *L. ligamentinus*, and *L. luteolus*. There were not many live mussels to be found in this stretch of the river, probably on account of disturbances caused by the hauling of sand.

There were also few found below the riffles, as the stones were too thick in the river bed to furnish any foothold. The shell bed itself was therefore on a slope between the shallower portion of the riffle and the deeper sandy bottom upstream. The bottom on which the

mussels were located was composed of mingled sand and pebbles. The water over the mussel bed was shallow, averaging about 2 feet in depth during the period of observation, and the current was moderate, 3 or $3\frac{1}{2}$ miles per hour. The water varies considerably in depth and turbidity at different times; even a small local shower raises the surface perceptibly and makes the water very muddy, after which it slowly abates in volume and becomes clear. While this mussel bed was under observation it was occasionally rendered unworkable for a few days by local showers. On the other hand, the water was sometimes found clear enough to see the bottom with a fair amount of distinctness.

The life conditions of the riffles and the swimming hole just above it were studied in considerable detail. The river flora did not appear to be particularly rich. The only conspicuous alga was a species of *Oscillatoria*, which was very abundant on the surface in large floating blue-black patches from which the filaments radiated in every direction. Of phanerogams, the only aquatic plants growing in the river at this place were eelgrass or wild celery (*Vallisneria spiralis*) and the dense-flowered water willow (*Dianthera americana*).

The animal life was rich and rather varied. One of the most abundant animals was a *Vorticella*-like protozoan, probably *Epistylis*, which thickly covered with a uniform hoary coating the blades of *Vallisneria* and the branches and leaves of willow which dipped into the water. The same or a similar protozoan grew in great abundance on the crawfishes of all sizes, especially thickly on the antennæ, which were rendered quite white and plumose. Examples of the protozoan taken from the crawfishes showed the zooids thickly clustered at the apex of a long nonretractile dichotomously branching stem. On account of the nonretractility of the stem, this white coating can not contract into a mass when irritated as can colonies of *Vorticella*. A small colony of *Vorticella* was found clustered on an *Ataxe* taken out of a mussel. A species of fresh-water sponge was very common below the shell bed, frequently coating the inside of dead valves with an expanded thick feltlike covering. The brown hydra (*Hydra fusca*) was quite abundant, and numerous examples were seen attached to the back of shells of *Ancylus*. Leeches did not seem to be abundant; the only one noted was a fish leech attached to a sunfish caught in the river.

In addition to the mussels, discussion of which will be reserved till the end of the description of the locality, various univalves such as *Pleurocera*, *Physa*, and *Ancylus* were common.

The crawfishes were so abundant at this place as to deserve special mention. So far as examined the species was *Cambarus virilis*

Hagen, and the river bottom appeared to be almost overpopulated with them. The young were often seen crowding up close to the shore. As noticed above, many were thickly covered with a growth of protozoa, and some of the young were covered with a green algal growth. In the mussel bed the crawfishes were seen sunning themselves on the rocks which projected out of the water, lifting themselves high upon the pincers in a most peculiar fashion. Upon wading out to a large projecting rock situated in the river about in the middle of the mussel bed they were found to be clustered thickly on the sloping surface of the rock just at the water line, their heads projecting out of the water. Many were found living in dead mussel shells just below the bed; indeed, it was hardly possible to pick an old shell or tin can out of the water without obtaining a crawfish. Some of those thus captured were of very large size. The crawfishes were frequently observed devouring the flesh of dead mussels, but it is doubtful whether they were able to kill any, especially the larger ones. They may possibly be an intermediate host of some of the mussel parasites. The crawfishes were caught in considerable numbers, either by dip nets or minnow seines, for fish bait and were used in the St. Joseph River. On July 2 a man was observed seining crawfishes just below the mussel bed at the riffles. The seine was drawn over the bottom, which was covered with rounded pebbles about the size of hen's eggs or larger, and the ends of the brails poked about among the rocks. The crawfishes, of which it seemed there was one under nearly every stone, backed up into the net and were caught in great numbers. The fisherman wanted only the soft-shells and "peelers" (crawfishes about to molt) and threw the rest back. A great number were molting at the time. The "peelers" can be easily distinguished from other crawfishes by pressing the sides of the carapace, which arches up free from the body. They also have a somewhat different color. The molted carapaces of crawfishes and gastroliths associated with them were quite common along the shore of the river.

No crustaceans except crawfishes were noted in the river itself, though small Entomostraca were abundant at the edge of the river, in overflow pools.

Aquatic insects and larvæ did not appear to be particularly abundant so far as species were concerned; a few forms, however, were quite common. The red "blood worm" (a *Chironomus* larva) was present in large numbers, and along shore, just under the water surface and attached to submerged objects by a short slender pedicel, was a great number of small gelatinous pear-shaped objects full of minute dots, probably egg bunches of *Chironomus*. Midges were abundant, emerging in great numbers; on the morning of June 21

there were many exuviæ on the water surface and on objects along shore. Many of the insects died shortly after emerging.

On the first visit to the swimming-hole, the afternoon of June 14, a large number of johnny darters (*Boleosoma nigrum*) and a few minnows were observed dead along shore. All the fishes were quite small, apparently the young of the year. It is very likely that some sudden pollution of the river about that time was the cause of the death of the fishes as well as that of a great number of large crawfishes on shore and mussels in the water. Some time during the summer it was reported that dyestuff had been poured from the knitting mills some distance above into the river and had caused a wholesale destruction of fishes, which died in such numbers as to render portions of the city along the river scarcely habitable. In addition to the dead fishes mentioned above, the following species were observed: Catfishes (young, probably *Ameiurus natalis*), mad toms (*Schilbeodes gyrinus*), golden shiners (*Abramis crysoleucas*), carp (*Cyprinus carpio*), and sunfishes (*Eupomotis gibbosus*). In the previous year a number of small black suckers (*Catostomus nigricans*) were seen at this place.

Of reptiles, a few painted turtles (*Chrysemis marginata*) were found. There were no indications of aquatic mammals, such as tracks or piles of shells along the shore. Late in autumn, however, a good many crawfishes were seen along shore with backs bitten open, and this may have been done by a muskrat or a mink.

As has been said, although a few mussels could be found above the main bed, the greater number were to be obtained just at the head of the riffles in a fairly compact bed. The mussel bed itself is quite small, probably not more than 2,000 square feet in extent, and commercial operations would clean it out in a very short time. On several occasions the water was clear enough to see the bottom and the distribution of the mussels fairly well. The mussels did not appear to be moving. They were headed mostly downstream, the natural position for feeding mussels, and were not deeply buried; about half of the shell projected out of the mud. The projecting portion was more or less stained and frequently covered with an algal growth.

On June 20 this bed was gone over with considerable thoroughness and a number of mussels collected. These were placed on shore, counted, and sorted over, and, after a number of representative shells such as were desired for specimens were picked out, the rest were thrown back. All the shells, especially *L. rectus* and *L. ligamentinus*, were large and fine. A number of the living animals were measured and weighed, with the results shown on the next page.

MEASUREMENTS AND WEIGHTS OF ST. MARYS RIVER MUSSELS.

Serial No.	Species.	Length.	Height.	Thickness.	Weight.
		mm.	*mm.*	*mm.*	*Ounces.*
1	Quadrula undulata	115	85	48	10.75
2	....do	104	77	45	8.25
3	....do	102	82	44	8.50
4	....do	86	67	35	4.75
5	....do	80	60	35	3.75
6	....do	76	60	31	3.50
7	....do	72	57	30	3.00
8	Lampsilis rectus	158	70	50	13.75
9	....do	159	67	47	14.50
10	....do	134	60	40	7.75
11	....do	150	66	47	13.75
12	....do	153	74	48	12.75
13	....do	141	66	42	12.50
14	....do	154	68	50	8.75
15	Lampsilis ventricosus	126	90	54	13.75
16	....do	110	80	45	8.25
17	....do	83	67	40	4.75
18	Lampsilis ligamentinus	137	83	53	16.50
19	....do	135	84	55	15.50
20	....do	145	88	58	18.25
21	....do	135	83	55	15.75
22	....do	131	82	58	14.75
23	....do	132	80	49	13.75
24	....do	130	80	49	11.75
25	....do	126	79	51	12.00
26	....do	131	79	52	12.75
27	....do	122	79	48	12.25
28	....do	115	79	48	10.75
29	....do	97	63	40	5.25
30	....do	120	75	55	11.75
31	....do	122	80	45	10.00
32	Lampsilis luteolus	124	70	46	9.25
33	....do	127	73	52	10.75
34	....do	134	71	49	11.00
35	....do	127	74	56	11.75
36	....do	126	76	50	10.75
37	....do	118	69	51	9.25
38	....do	102	60	48	6.50
39	....do	92	60	37	4.00
40	Symphynota costata	123	68	36	6.75
41	....do	95	56	28	3.25
42	....do	111	65	31	4.75
43	....do	113	66	38	5.75
44	....do	95	55	27	3.00
45	....do	111	60	33	5.25
46	....do	101	55	29	3.50

Below the mussel bed and also in it were a large number of dead shells. These were covered with water and appeared to be still as good for commercial purposes as ever, since they retained their original texture and luster. Some of the shells that had been longest dead were stained black, perhaps from iron in the water, but this color was superficial and could have been easily ground off. The mussels appeared at the time of our visit to be dying in some numbers, for a good many still retained the position they had during life and the flesh was still clinging to the interior of the shell. Some of the larger living shells were diseased and stained brown or green in the neighborhood of the cardinal teeth.

The stomachs usually contained considerable mud, in which was scattered a few diatoms, *Scenedesmus*, *Phacus*, etc.; the amount of organic material was quite small. The results of studies of stomach

contents are given in detail under the general heading at the close of this report. (See p. 57.)

When examined in June these mussels were strikingly barren. The only gravid individual noted was an example of *Lampsilis ventricosus* with the shell of a marked female contour very much inflated, and this was partly barren, the gills appearing shrunken. Subsequent investigations showed that the sterility of this bed was due partly to the season. As we went downstream and the season advanced we noticed gills of various species beginning to take on a dusky tinge at the margin and filling up with fertilized eggs and glochidia. Moreover, on a visit to this mussel bed on September 21, of 28 examples of *L. ligamentinus* procured 8 were gravid. The other species procured in September were: *Quadrula tuberculata*, 1; *Q. rubiginosa*, 1; *Q. undulata*, 3; *Symphynota complanata*, 1; *Lampsilis rectus*, 3; *L. luteolus*, 2; none gravid. The percentage of breeding mussels was hardly as great as one might expect under favorable conditions. No small shells were found, the smallest being of medium size and apparently several years old. The conditions on the whole seem to indicate that this mussel bed is dying out. It would have been possible to secure a number, perhaps a half ton, of good shells here without disturbing the mussels.

The riffles were incidentally visited in November, and although the water was quite cold the protozoa were still abundant on crawfishes and dead leaves in the water, and the conditions bore considerable resemblance to those observed earlier in the year.[a]

None of the mussels was badly parasitized.[b] *Atax ypsilophorus*, *Aspidogaster conchicola*, and *Cotylaspis insignis* were rather common, but not abundant. The marginal cyst distomid was rather frequent, and it was here we obtained material with which we were able to associate this organism with pearl formation. It was most common in *Lampsilis ligamentinus*.

From the riffles down to the mouth of the river mussels appeared to be quite scarce.

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[a] On June 26, 1909, as opportunity permitted, this place was revisited. It was during a long period of high water. The river, though turbid, was not filthy and appeared reasonably clean. At the riffles it was racing at a rapid rate and the current could hardly be stemmed when about breast-high, but would sweep one off his feet. No Protozoa were seen, and only a few young crawfishes, which were very active and alert. A few gray-back minnows were swimming about on the surface, and schools of small minnows darted from shore. By wading about a great deal only two live mussels (*L. ligamentinus*) were found, though there were a number of dead shells. There were no evidences of unhealthy conditions or overcrowding; on the contrary, the conditions seemed to be those of an ideal mussel stream. This visit served to emphasize the fact that during periods of high water sewage is comparatively innocuous and that while the water of the river has great variation the river population is fairly constant; in periods of low water the stream is overpopulated and, to use a chemical phrase, the inhabitants are almost precipitated out.

[b] The parasites are more fully discussed and described at the end of the report.

Station C. Spy Run.—Spy Run is the name of a small shallow stream which enters the St. Mary's about a half mile above its mouth. The bottom is of fine sand and the water at the time visited was quite clear. There were many small fishes, chiefly the johnny darter (*Boleosoma nigrum*), a few golden shiners (*Abramis crysoleucas*) and chubs (*Semotilus atromaculatus*), and a number of crawfishes, all free from Protozoa. No living mussels were found, but about a dozen dead shells, all of which, except fragments of one *Lampsilis iris*, were *Anodontoides ferussacianus subcylindraceus*.

ST. JOSEPH RIVER AND FEEDER CANAL.

The St. Joseph River, more commonly known by the shortened local name St. Joe, is a larger and clearer stream than the St. Marys, and since only the very lowest portion of its course enters the city, it is much freer from sewage.

Station D. St. Joseph River at Robinson Park, 6 miles north of Fort Wayne.—The highest point at which the St. Joseph River was examined was at Robinson Park, a pleasure resort about 6 miles above the city. This point could easily be reached by trolley. Considerable change had taken place in the river here within the last few years. At the time the park was established there was a dam in the river which had kept the feeder canal, just above, full of water. This had raised the water of the river and had expanded it somewhat into a quiet, pondlike basin. The breaking of the dam had reduced the water to its normal height and emptied the canal.

At the time of our visit the river was rather high and turbid from recent rains. We procured a boat and rake at the park and rowed up to the riffles about half a mile above the park, examining the river and shore.

There was a fair number of shells scattered along here, all of which were large and of excellent luster. The large shells found at the park itself had been dead some time, and may have been killed by the lowering of the water when the dam broke; the *Lampsilis luteolus* were exceptionally large and fine. Farther up the stream large dead shells were collected on the bank, chiefly *Quadrula undulata*. They were freshly dead and had probably been killed for bait. On investigating the river it was found full of snags in some places; in others the bottom was of hard clay, too compact for mussels to live in. In the beds of gravel where mussels were likely to be found the bottom was full of sharp rocks which in the turbid water were difficult to distinguish from mussels, so that collecting the latter was uncertain. We found very few live shells, but were told that they were easy to obtain when the water was low and clear.

The manager of the boathouse at Robinson Park told us of having seen a good bed of mussels here during clear low water. He also reported that where he used to live on the Ohio River they ate the "small sweet mussel," but the larger kinds were too tough for food, except that they could be used for flavoring soup.

Station E. Feeder canal from Robinson Park to Fort Wayne.—In the days of the Wabash and Erie Canal, the dam mentioned above was built across the St. Joseph River just below what is now Robinson Park, and a feeder canal was dug to convey the water from above the dam to the main canal at Fort Wayne. After the main canal had fallen into disuse this feeder was still used as a source of power for mills at the outskirts of the city, and the water was turned back into the St. Joseph River.

When Robinson Park was established the canal formed a charming water lane leading from the city out to it. About the summer of 1906 or 1907, however, the dam in the river broke and let the water out of the canal.

The dry canal bed offered one of the most remarkable opportunities possible for the study of mussel distribution within a small area. It was 6 miles in length and, with the exception of a few places below the general level, it dried up so quickly that the mussels are still left in their original positions in the mud on the bottom of the canal. The shells are half to two-thirds buried in the dried mud, the great majority of them with the posterior end directed northward—that is, against the current when the canal was full of water—and with the valves nearly closed, just as the animals died.

This region had been visited and preliminary studies made in the autumn of 1907, and it presented the same features that it did early in the summer of 1908—a long, dry, and cracked mud flat forming a vista of projecting shells, the short tracks the mussels had made during life being still distinct. In the canal bed it was possible to study all the species that had lived there, their abundance, distribution, and the like. Many of the young shells of *Lampsilis luteolus* exhibited brilliant rays; they appear to have been exceptionally highly colored.

Toward the upper end of the canal, in a place where the bottom was 15 feet wide, the mussels were counted for a stretch of 10 feet along the canal bed and the following species noted: *Quadrula rubiginosa*, 11; *Q. cylindrica*, 1; *Q. undulata*, 86; *Anodonta grandis*, 6; *Ptychobranchus phaseolus*, 1; *Lampsilis ligamentinus*, 5; *L. luteolus*, 6. The width taken was the total width of the bottom of the canal and was considerably wider than the space occupied by the mussels.

About a mile farther down the canal a space 10 feet square was measured off in the bottom of the canal and the following species

were found: *Quadrula rubiginosa*, 6; *Q. undulata*, 60, all rather small; *Pleurobema clava*, 1; *Alasmidonta truncata*, 2; *Symphynota complanata*, 2; *S. costata*, 5; *Anodonta grandis*, 15; *Obovaria circulus*, 4; *Lampsilis ligamentinus*, 5; *L. luteolus*, 1; *L. ventricosus*, 4. This gave a little over 1 shell per square foot. In 1908, in a square meter of bottom near the Rod and Gun Club, the following species were noted: *Quadrula rubiginosa*, 9; *Q. undulata*, 36; *Symphynota complanata*, 1; *Anodonta grandis*, 17; *Obovaria circulus*, 11; *Lampsilis iris*, 2; *L. ligamentinus*, 2; *L. luteolus*, 3, giving a total of 81 per square meter. In addition to these shells there were many small *Sphæriums*, the ground being paved with them, 34 *Campelomas*, and 23 *Pleuroceras*. The square meter referred to above represents, as nearly as could be judged, an average number rather than either extreme.

The general impression obtained concerning the abundance of various species is given in the table on page 37.

Figure 2, plate 1, represents a portion of the dried canal bed near its upper end. It shows admirably the mud cracks formed on drying and the mussel shells still protruding in situ.

Realizing the value of an opportunity to study so extensive a tract with the mussels still in their original positions and in plain sight, several visits were made to the canal, and as a result the following conclusions were reached:

1. Each of the species found was well distributed throughout the entire canal; that is, there was no marked gathering together or colonizing of any one species to the exclusion of others. So fully was this true that a careful examination of a few rods of the canal bed anywhere was reasonably certain to yield specimens of all the species, except possibly one or two that were very rare. In this connection it must be kept in mind that the bed of the canal was very different from that of a river, in that it was practically the same throughout its entire length. It was all shallow mud, with little sand or gravel; the water was of nearly uniform depth, and the current was of uniform rapidity. In short, there was almost nothing except the consistency of the mud upon which a mussel could base any preference of locality. Slight differences in this respect caused an increase in the numbers of mussels in some places, but affected all the species equally.

2. The number of mussels which can find accommodation under fairly favorable conditions upon a definite area in the canal bottom may be judged by the counts on measured areas given above.

3. A canal makes an excellent breeding ground for mussels, as was particularly attested by the presence of a large number of younger examples among the adults, showing all stages of growth. The current in the canal appears to have been just fast enough, food material

Fig. 1.—Bed of Maumee River just below Columbia Street bridge, Fort Wayne, Ind., showing mussels killed by sewage from city gas works.

Fig. 2.—The dried bed of the Feeder Canal, showing mud cracks and mussel shells in situ.

Fig. 3.—Pile of shells, chiefly muckets, *Lampsilis ligamentinus*, containing 25 tons, gathered from the Maumee River near Fort Wayne, Ind.

constant and ample, the supply of water uniform the year round, and the bottom seems to have been well suited to a great variety of species. This gives the mussels a uniformly large size, while the shells at the same time are of extra quality and luster.

4. These facts would indicate that a canal would furnish one of the best locations that could be obtained for artificial propagation of mussels. Furthermore, the water in a canal can be drawn down from time to time without much trouble, thus allowing examination of the mussels. Examples suitable for breeding or for commercial purposes could then be selected easily and rapidly without in any way disturbing the others. Such possibilities are at least worthy of a careful consideration in future attempts at the artificial propagation of mussels.

The last visit to the canal was made on July 27, after a series of heavy rains. The canal bed was at this time under water for nearly its entire length, and was covered with grass and weeds that had sprung up in a short time and effectually concealed the shells. This visit threw light on a phenomenon which had proved quite puzzling during previous visits. Occasionally, shells of *Quadrula undulata*, only recently dead and with bits of flesh still clinging to them, had been found in dry places in the canal bed some distance from any pool. At the time it was hard to understand how they came to be there, as it seemed impossible that they could have "mudded up" and survived the long period following the breaking of the dam. This visit showed that during the high water of winter or spring the whole canal bed had probably been submerged, and that the mussels had migrated from the deeper portions at that time.

During our previous visits, also, a number of pools, comprising the deeper portions of the canal bed, were observed, and a few live mussels, chiefly *Anodonta grandis* and *Quadrula undulata*, had been noted near the edges, but the pools were not fully investigated.

On this last visit the pools were thoroughly investigated and were found to contain an abundance of molluscan life. Fine examples of the following species of mussels were secured: *Quadrula coccinea*, 1; *Q. rubiginosa*, many, deeply buried; *Q. cylindrica*, 1; *Q. undulata*, many; *Alasmidonta truncata*, 1; *Symphynota costata*, several; *Anodonta grandis*, a few; *Strophitus edentulus*, a few; *Ptychobranchus phaseolus*, 1; *Obovaria circulus*, 1; *Lampsilis iris*, 1; *L. rectus*, 2; *L. ligamentinus*, many, large and fine; *L. luteolus*, several; and *L. ventricosus*, 1, large. Among other mollusks, *Ancylus* was abundant and large, usually attached to the shells of living mussels. Algæ of various species were common, covering the water surface. In one place *Hydrodictyon* was exceedingly abundant.

This investigation was interesting and important, as it showed that mussels will live for long periods in shallow pools where they once

have obtained foothold, even though the conditions under which they once throve and multiplied have ceased. While it is true that mussels die rather quickly when placed in foul water or unfavorable conditions, both our investigations here and our experiments in transplanting elsewhere indicate that they can live for long periods where they probably would not naturally develop, and that they can easily be stored in pools of limited size.

Station F. Reservoir of the feeder canal.—This is an artificial pondlike area at the lower end of the canal and within the outskirts of the city of Fort Wayne. This reservoir, which originally connected with the canal, covers about an acre, and the water, which at the time of our visit was only a foot deep at most, probably never gets much deeper, as it can easily drain into the river below. The bottom of the reservoir is of a bare, yellowish clay, and there is a great deal of miscellaneous trash over it, indicating that it has been used to some extent as a sort of dumping ground. There were quite a number of mussels in this pond. *Quadrula rubiginosa* was common in the warm shallow water near shore, and on the date of our first visit (June 30) was remarkably active, almost every example being at the end of a long, curved track. They were quite high up out of the mud, and several had fallen over and were lying on their sides. *Quadrula undulata* and *Anodonta grandis* were also common, and there were a few *Lampsilis luteolus*. Some dead *L. glans* and one dead *L. ventricosus*, which quite closely resembled *L. capax*, were found along shore. More very young mussels were seen here than anywhere else. They were at the end of long, narrow tracks resembling snail tracks, in the shallow water along the north shore of the pond, and were nearly buried in the mud, only the posterior tip of the shell slightly projecting. Their presence indicates that the reservoir was used quite actively as a breeding ground for the mussels. There were a few fishes in the reservoir, chiefly carp and suckers, and boys were occasionally seen fishing there. Other mollusks, especially large *Campelomas*, were abundant.

The mussels of this place, especially the *Anodontas*, were more heavily infested with parasites than those obtained anywhere else, with the exception of some *Lampsilis alatus* taken at Grand Rapids, Ohio, which contained *Atax* in great numbers. The common mussel parasites, *Atax*, *Cotylaspis*, and *Aspidogaster*, were present in nearly every individual examined.

The reservoir was again visited on July 23, and it was found that the *Quadrula rubiginosa*, which on the previous visit were high up out of the mud and actively moving about, had by this time buried themselves deeply. It was also noticed that at the same date, in the pools of the canal itself, they were likewise deeply buried. It is probable that their great activity during our first visit was due to

restlessness caused by the warmth of the shallow water and that their action of deeply burying themselves was in anticipation of the drying up of the reservoir. A number of the *Anodontas* obtained at this time were examined as to food and parasites, with the following results:

No. 1.—Parasites: *Atax*, 3, in gill axils; *Cotylaspis insignis*, 1, in axil of inner gills; *Aspidogaster conchicola*, 2, in pericardial cavity. A small patch of *Plumatella polymorpha* on each valve. Gills empty, but ova in the body. Stomach contents ample, brownish green in mass, containing a few *Scenedesmus* and numerous globular organisms, probably *Trachelemonas*.

No. 2.—Parasites: *Atax*, 27, in axils of gills; *Cotylaspis insignis*, 8, in axils of inner gills; *Aspidogaster conchicola*, 8, in pericardial cavity. Shell deeply stained a salmon color on the inside, with a tadpole-shaped blister on the left valve near the siphonal opening. Considerable *Plumatella polymorpha* on the outside of the valve. Stomach contents fine greenish brown in mass, mostly of unrecognizable material, and containing several *Scenedesmus*, 1 *Pediastrum pertusum*, and 1 shell of rotifer *Anuræa cochlearis*.

No. 3.—Parasites: *Atax*, 43, between and among the gills, chiefly in the axils; *Cotylaspis insignis*, 2, axils of inner gills; *Distomum* of Osborn about 248, on outside of mantle, between mantle and shell; *Aspidogaster conchicola*, 8, in pericardial cavity; Sporocysts (*Distomum* of Osborn) innumerable, distributed thickly throughout the mantle. Stomach contents, chiefly minute green and black globules, probably *Cryptomonas*, and 1 diatom, *Pleurosigma*.

No. 4.—Parasites: *Atax*, 8 large, 2 small, in gill axils. The large ones were full of eggs. *Distomum* of Osborn, 58, 30 on the right side near the umbo ("right shoulder") and 28 on the left; *Cotylaspis insignis*, 9, in axils of inner gills; *Aspidogaster conchicola*, 2, in pericardial cavity. Stomach and intestine almost empty, but contained *Trachelemonas*, *Gamosphæria aponia*, and a spindle-shaped *Euglena*-like organism. Nacre stained a deep salmon color, with a good deal of *Plumatella* on the outside.

No. 5.—Parasites: *Distomum* of Osborn, 33 on the "left shoulder" and 35 on the right; sporocysts of that species innumerable throughout the mantle, the cercariæ escaping from them and present in large numbers; *Atax ypsilophorus* 32; *Atax*, small species, 18, between gills; *Cotylaspis insignis* 11, in axils of inner gills; *Aspidogaster conchicola*, 5, in pericardial cavity. The intestine contained numerous minute dark-green globules (*Trachelemonas?*), which were moving about actively. It also contained the *Euglena*-like organism, and *Anuræa cochlearis*, 1 empty shell.

No. 6.—Parasites: *Distomum* of Osborn, 23 on the "right shoulder" and 12 in the left; *Atax* 50, in the axils of the gills; there were many *Atax* eggs, which are minute yellow objects, on the inner side of the mantle. Two species of *Atax* present, a large and a small, both full of eggs. The eggs in the mantle were hatching, and the larvæ were present in the different stages of development; *Cotylaspis insignis* 4, in the axils of inner gills, and *Aspidogaster conchicola* 13, in the pericardial cavity. The shell had considerable *Plumatella polymorpha* attached; the nacre was stained a deep salmon, and there was a raised ridge on the right valve from the umbo downward and backward.

No. 7.—Parasites: *Atax intermedius* 14, in axils of gills, and with the eggs scattered on the inside surface of the mantle; *Distomum* of Osborn about 100, on the "shoulders"; *Cotylaspis insignis* 9, in the axils of the inner gills; *Aspidogaster conchicola*, 2, in pericardial cavity. The alimentary canal of this example was empty. Interior of the shell with a row of four salmon-colored

groups of knobs opposite each "shoulder" and extending from the hinge two-thirds of the way to the edge of the shell. Three straight ridges, also salmon-colored, on the left valve, radiating from the distal end of the row of knobs. The salmon marks in the nacre corresponded exactly with the position of the distomids in the mantle. There were three bunches of distomids corresponding to the three ridges on the left side.

No. 8.—Parasites: *Distomum* of Osborn, about 200 on the outside of the mantle at the "shoulders," but no sporocysts present. *Atax intermedius* 14, *Atax aculeatus* 3, and several examples of *Atax ypsilophorus*. The *Atax* contained large eggs, and all the animals were located between the gills; *Cotylaspis insignis* 2, in the axils of the inner gills; *Aspidogaster conchicola* 5, in the pericardial cavity. There was a good deal of *Plumatella polymorpha* on the shell. The color of the nacre was pretty uniform, but somewhat more intense in the region of the umbones, where the distomids were also thickest. Alimentary canal full of *Trachelomonas*, with a few diatoms and *Scenedesmus*. The *Trachelomonas* were very actively swimming about, although they had been in the stomach of the mussels for at least 36 hours.

No. 9.—Parasites: *Atax* 23, between the gills; the eggs abundant, and some young hatched; *Distomum* of Osborn 3, on "shoulders" as usual; *Cotylaspis insignis* 3, in axils of inner gills; *Aspidogaster conchicola* 7, in pericardial cavity. The alimentary canal contained rather numerous *Scenedesmus*, 1 *Pediastrum pertusum*, 4 *Anuræa cochlearis*, and 1 spindle-shaped *Euglena*-like object.

In a day or two after the visit to the reservoir in which these mussels were obtained, it was revisited. The pond was covered with a green scum, but there was no opportunity to examine it more fully.

The collections at this place were particularly interesting because of the knowledge obtained concerning stages in the life history of the distomid of Osborn, sporocysts of which were especially abundant in mussels no. 3 and 5. These matters are more fully discussed under our notes on parasites toward the end of this report. (See p. 61.)

Station FF. Feeder canal between the reservoir and the Maumee River.—The feeder canal with its reservoir may be regarded as a sort of auxiliary channel of the St. Joseph River from Robinson Park down to the city. The mussels were, however, much more evenly distributed in the canal bed than in the river bed. The latter was examined from the reservoir of the canal down to the mouth of the river, but only occasional mussels were obtained above Wagner Street Bridge.

Station G. St. Joseph River at Wagner Street, Fort Wayne.—At Wagner Street there was a very good shell bed, which was examined pretty thoroughly. The river here is shallow, with a gravel bottom, and the current during ordinary stages of the water is about 2 or 2½ miles an hour.

A little below this station there appeared to have been a fair bed of mussels; but sand was being hauled from the river in large quantities, and the disturbance was unfavorable to molluscan life.

The men hauled many shells with the sand. A fine example of *Lampsilis ventricosus* was observed spawning here on July 20. Just above where the men were hauling, *Quadrula rubiginosa*, a few *Symphynota costata*, some *Lampsilis luteolus*, and a large number of *L. ligamentinus* were seen. Where the men were at work a number of the rarer shells, *Pleurobema clava* and *Truncilla sulcata*, were obtained.

Station H. St. Joseph River just above its mouth.—One of the finest beds was just at the mouth of the St. Joseph River, extending upstream about 20 rods, and as the condition of the river was quite favorable this was examined several times. The bottom was of fine sand and the water from a few inches to about 3½ feet deep, and quite clear, so that the mussels on the bottom could be seen fairly well. There was nearly a bushel of shells on shore, which had been crushed by boys in search of pearls.

The mussels had been moving about to some extent and appeared to be, on the whole, quite active. While most of them were deeply buried and were headed downstream in their natural feeding position, a few were transverse to the current, and none showed the sharp line of demarcation on the shell that is usually found where the animals occupy the same position for a long time. Of this collection recorded in the table, 9 species, *Q. rubiginosa*, *Q. pustulosa*, *Q. undulata*, *S. complanata*, *P. phaseolus*, *L. rectus*, *L. ligamentinus*, *L. luteolus*, and *L. ventricosus*, represented by 208 shells out of a total of 341, were good button shells. This is a considerably lower percentage than a little farther down in the Maumee, as the proportion of marketable shells is considerably reduced by the abundance of the comparatively worthless *Symphynota costata*. The merchantable species were easy to obtain and also of large size and excellent quality. While we were at work on this shell bed on July 21, the clammers who had been working in the Maumee below entered the mouth of the St. Joseph. This date, therefore, marks the beginning of clamming operations on this river. The clammers had at the time about 800 pounds of shell in their boat, chiefly *Lampsilis ligamentinus*, which they had secured in the Maumee below.

MAUMEE RIVER.

During the autumn of 1907 preliminary investigations were made along the first few miles of the Maumee. Shells appeared to be fairly abundant, but were for the most part ignored by the local inhabitants. In general, no attention was paid to them except that they were occasionally used for fish bait, and people knew little about them. A considerable pile of scattered shells was seen in a yard adjoining the river, and the owner of the place said he had gathered the mussels to feed his ducks, which were very fond of

them. Among the shells found in the yard were some fine *Lampsilis ligamentinus*, and a rather thick ventricose form of *L. alatus*. There was no clamming for button shells in the river and little or no pearling.

In the summer of 1908 a prospecting trip along the first few miles of the Maumee discovered a clammer's camp, which will be spoken of more fully later on. (See p. 27.) The camp was visited several times during preliminary field work.

The boat was launched July 29 just below the Columbia Street Bridge in Fort Wayne, which marks the head of the Maumee, and August 9 we reached Miami, Ohio, 7 miles above Toledo, where the river enters Maumee Bay. The party proceeded downstream by easy stages, examining the river's bottom for mussels wherever there were indications of their presence, stopping overnight at one of the towns or villages along the river or at a convenient farmhouse. Defiance and Grand Rapids, Ohio, were the only places where any stay was made. At Defiance the Tiffin and Auglaize Rivers enter the Maumee, each of them nearly as large as that stream itself, and three days were spent examining them. At Grand Rapids an extra day was devoted to the long riffles below the dam. The old Miami and Erie Canal is still in operation from Defiance to Toledo. This afforded a way of getting past the dams and riffles and gave promise of being itself rich in mussels. As it kept so close to the river that the latter could be visited easily at any time, the party chose the canal for the remainder of the trip. The following is a summary of the stations with the species found at each and their relative abundance.

As previously stated, the stations were numbered consecutively, and the numbers appearing with the species represent the specimens of each that were obtained.

Station 1. Maumee River at its source.—This includes the first 2 or 3 miles of the river and the clammer's camp.

At the very head of the river, just below the Columbia Street Bridge, an immense bed of dead shells was found, forming banks and bars. The entire bottom of the river and the south bank for some distance out of the water were literally paved with shells, chiefly muckets (*Lampsilis ligamentinus*).

Some idea of the number of these shells can be obtained from figure 1, plate 1, in which every one of the objects upon the bank is a dead shell. In all probability these mussels had been killed by the refuse from the gas works which are situated on the bank of the St. Marys a few rods above its junction with the St. Joseph. Spots of tar were found on dead mussels some distance below this point. The water was covered with an oily scum in places and a tarry odor was perceptible for several miles down the river.

The bottom of the river at its head is Devonian limestone, and the banks are of white clay; the average depth of the channel at the time examined was about 3 feet and the current about a mile an hour.

A mile and a half down the river was the clammer's camp. This was the only one on the river and had been established but a short time. The owner, Mr. H. S. Birge, had formerly lived on the Wabash, where shelling operations are active, and had done considerable clamming there. He had come to Fort Wayne to work on the construction of a canal, and finding this work slack at times, had naturally turned to the river and begun investigating its clamming possibilities. He reported clamming "fairly good but not as good as one might expect from the looks of the river." As the bottom was rough and stony with occasional snags and the water fairly shallow, he procured shells in the same fashion that they are obtained in parts of the lower Wabash—by scooping them up with a coal fork, the operator standing waist deep in water. In three weeks' time, with the help of his brother and two young boys, the clammers had gathered 25 tons of first-quality shells, mostly "muckets" (*Lampsilis ligamentinus*), with a sprinkling of good "long johns" or "black sand shells" (*Lampsilis rectus*), a few "pocketbooks" (*L. ventricosus*), etc. The shells were remarkably uniform in size and quality. There were few culls or worthless shells—less than a bushel. They consisted chiefly of *Lampsilis alatus*, a few *Quadrula tuberculata*, and an occasional *Unio gibbosus*.

Figure 3, plate 1, shows a pile of shells, with the cleaning table in the background, and gives a fair idea of their size. In the matter of pearls and baroques this lot of shells gave very meager returns; there were no baroques worth saving, and only two small and comparatively worthless pearls in the whole lot. Mr. Birge was impressed with the size and fine quality of the muckets of this region.

Station 2. Five miles below Fort Wayne.—A fair bed of mussels was found here, with many dead shells along the bank. The water was shallow with almost no current, the bottom muddy with an abundance of algæ.

Station 3. Kern Reservation.—There was here a large bar projecting out of water and covered with dead shells which had evidently been washed out during river floods. The river was free from sewage and the water was quite clear, about 3 feet at the deepest, and with very little current. The bottom was of rounded gravel well covered in places with algæ, and many good-sized sponges. There were also large numbers of flatworms on the stones and many *Ancylus*, while crawfishes were numerous and hostile.

The mussels were well bedded and quite abundant, but not very large. A sample collection was preserved, after which the others were thrown back. This was the first station at which *Q. pustulosa*

was obtained in abundance, although a few fair-sized examples were found in the feeder canal in 1907. Mr. Kern, whose farm extends along the river here, says that the mussels appear to be dying off more rapidly than formerly, due, he thinks, to increased pollution of the river by sewage.

Station 4. Near New Haven, Ind.—Just above the New Haven Bridge is a long stretch of the river with clear shallow water and gravelly bottom. Here a fairly thick bed of mussels was found. The crawfishes were especially numerous and pugnacious, and many of them were seen eating small mussels. It could not be ascertained whether they had killed the mussels or were merely feeding on some that had died from other causes. All the shells obtained were rather small. The *Q. undulata* were peculiar in that the ridges were considerably broken up into isolated portions somewhat resembling tubercles.

Symphynota complanata, which was one of the characteristic shells of the feeder canal and of which we obtained examples in the mouth of the St. Joseph, may have been introduced into the Maumee River through the agency of the Wabash and the Erie Canal. At the town of New Haven we were told of a remarkable shell that some boy had found along the river several years before, and which had been preserved as a curiosity. An examination proved it to be a characteristic specimen of this species. This was the farthest down the Maumee it was seen or heard of.

Station 5. Below New Haven, Ind.—This station was near a sand bar just below a long riffle. The water was from a few inches to 3 feet deep, and the bottom sandy, with many pebbles. There was an immense number of crawfishes here, one of which was eating a dead *Q. undulata*. Only a few live mussels were found. Among the dead shells were one *Alasmidonta truncata*, one *Strophitus edentulus*, several *Obovaria circulus*, and several *Lampsilis rectus*.

Station 6. One mile below station 5.—A small pile of shells was found on the river bank opposite a house owned by a man named Nieter. Some boys had been searching for pearls and had thrown the emptied shells together. Upon examination we found only three species.

Station 7. Four miles above Woodburn, Ind.—After leaving station 6 no indications of shell beds were noted until we reached the vicinity of Woodburn, Ind. Four miles above that town is a large gravel bar on the north bank of the river, overflowed at high water and covered with dead shells. Several live mussels were found in a pool on the bar and one or two were out of water and still alive, showing that they had come there during the recent high water. The list includes both living and dead shells.

Station 8. Woodburn, Ind.—Near Woodburn is a long series of riffles known as Bull Rapids, where shells appear to be abundant, but would be difficult to obtain, except during very low water, on account of the rocky bottom and the swiftness of the current. There was a long bar here covered with dead shells, but although we waded about everywhere over the coarse sand and rocks of the bottom, covering a large area, we found only a few live mussels. The party stopped for the night with a Mr. Armbruster, just below this station, and he reported finding in his cornfield on the south bank of the river a large pile of mussel shells some distance from the water, and made up of the same kinds as those found in the river. The presence of bones and stone implements among the shells left no doubt that this was an Indian kitchen midden, and that the aborigines had used these mussels for food.

Station 9. Maumee Center Bridge.—Just above Maumee Center Bridge some men were busy hauling gravel out of the river bed. There was a fair number of shells in the gravel, though by no means enough to indicate a shell bed, and the men were of the opinion that there were not many in the river. The water was turbid at the place, the bottom of gravel, and the depth 3½ to 4 feet. The species noted were found in the sand along the shore.

Station 10. One mile below Antwerp, Ohio.—The next place at which the river was examined was about a mile from Antwerp, Ohio. Just below the town the river has a width of 250 or 275 feet, with low banks, and there is a long series of riffles. The bottom is covered with coarse gravel and loose rocks. There were many dead shells on bars alongshore, while the live mussels were rather scattered and deeply buried among the rocks and pebbles.

Station 11. Five miles below Antwerp, Ohio.—This station was along the bed of the river opposite the farm of a man named Curtis. A long sand bar with a number of dead shells was seen. On the bar were noted a few *Quadrula rubiginosa*, several *Q. cylindrica*, a few *Q. undulata*, a large number of *Pleurobema clava*, a few *Unio gibbosus*, a few *Obovaria circulus*, several *Lampsilis iris*, a few *L. rectus*, and a large number of *L. ligamentinus*, which was the most common shell. Just above the bar the water was deep and sluggish and below it was shallower and swifter. In the deeper water the shells were widely scattered and deeply buried and consequently difficult to find. In the shallow water on the slope of the bar they were also well scattered, but had been actively crawling about and were easily found at the end of the tracks they had made.

Station 12. Ten miles above Defiance, Ohio.—The water was quite deep here and the river banks steep; the place was used as a swimming hole. The bottom was rather solid, composed of fine mud and sand and covered with a growth of algæ, among which was a large

handsome species of *Chara*. No shells were seen on shore, and after examining a large area of the bottom only 3 live mussels could be found: 1 *Unio gibbosus*, 1 *Lampsilis alatus*, and 1 *L. luteolus*.

Station 13. Tiffin River, just above Defiance, Ohio.—Tiffin River is a large stream entering the Maumee about a mile and a half above Defiance, Ohio. We had heard that there were mussels in the stream, and Kirsch[a] has reported them as abundant in the lake at the head of the river, although he says nothing of the river itself. The backwater of the Maumee, caused by the dam below Defiance, extends for about 2 miles up this river, so that it was a very sluggish stream with almost no current. A light-green thin scum, resembling *Euglena*, flowed slowly down, streaking the central portion of the river.

The banks and bottom were yellow clay, the water turbid, and so far as we could observe aquatic vegetation was lacking. We ascended the river about 2 miles. No shells were seen on shore and considerable dredging brought up only 3 live mussels, 1 *Lampsilis alatus*, 1 *L. ligamentinus*, and 1 *L. ventricosus*. The river was full of brush and snags which frequently entangled the dredge. It is quite likely that mussels are more abundant higher up beyond the dead water.

Defiance, Ohio, was reached August 2. Here the Maumee and Cincinnati Canal goes southward through the State. At the time of our visit this canal was nearly empty, as the locks were being repaired. This canal was followed on foot for some distance into the country, but no traces of mussels of any kind could be seen along the shore or in the mud in the bottom.

Station 14. The Auglaize River, 2 miles above Defiance, Ohio.—The Auglaize River is fully as large as the Maumee, and joins the latter at Defiance, the old Indian fort for which the city is named having stood upon the point of land between the two rivers. The water is considerably clearer than that of the Maumee, and the dead water backs up the river for some distance. Just beyond the dead water is a series of short riffles. Here the water was quite shallow and the bottom composed of a slippery horizontal shale which had been used to some extent in the manufacture of cement. The river is further broken up by a number of small islets and pools. Many large dead shells were found on the bars. The mussels could obtain no foothold in the bottom of the main portion of the river, since it was of bare shale, but were found in the sand and gravel bars along the banks. Here they were congregated into dense beds. Nearly the whole surface of the bars was covered with dead and living shells, even among the roots of the water willows and other aquatic plants. The water was clear and the current moderate, making the collection

[a] Bulletin U. S. Bureau of Fisheries, loc. cit.

of specimens easy. Shells of all the species found were large, some of them exceptionally so, being the largest of their kind we had yet seen. This was notably true of *Symphynota costata* and *Alasmidonta truncata*. The shells were also of the finest quality and best luster, making them very desirable material for commercial purposes.

The *L. ventricosus* were buried rather deeply and were comparatively hard to dig out. *Quadrula pustulosa*, which had been dwarfed thus far in the Maumee, was here of good size. It will be noted that several species were found here which had not been encountered before, viz, *Quadrula lachrymosa*, *Plagiola donaciformis* and *elegans*, and *Obliquaria reflexa*. (See fig. 5, pl. II.)

Station 15. The Auglaize River, 4 miles above Defiance.—The success at station 14 determined us to try the river again 2 miles farther upstream. The bottom was much the same as at the previous station, except even more slippery and with fewer islets; and the only place the mussels could obtain any foothold was in sheltered coves alongshore, now on one side and now on the other, according to the current and swing of the river. The coves differed somewhat as to bottom, some being sandy or gravelly and others muddy. The shells found here included more of the smaller species than at the preceding station, although there were also some very large ones. On one of the fine gravelly bars a number of mussels, chiefly of the smaller species, were very actively crawling about in the shallow water; a recent shower had probably moved them out of their places and they were readjusting themselves. Here was found the only living example of *Truncilla sulcata* seen during the whole summer's work. In the protected coves with muddy bottom *Anodonta grandis* was the most common shell. *Lampsilis ligamentinus* was just beginning to show an approach to the gravid condition; the lower edges of the outer gills were becoming faintly distended and margined with black. *Ptychobranchus phaseolus* was considerably further advanced, the gills being thrown into wavy folds. There were many small schools of minnows here, which kept nibbling at our feet and ankles when we waded into the stream and which clustered eagerly about bits of bread which we threw into the water.

Among mussel parasites the marginal-cyst distomid was quite common, and there were a few *Atax* and *Cotylaspis* present. The *Anodontas* were heavily infested with *Atax* and the distomid of Osborn.

Station 16. Maumee River, 4 miles below Defiance.—Four miles below Defiance a State dam, 7 feet high, crosses the river. This dam, known also as the Independence Dam, was built by the State of Ohio to make the river a feeder to the Miami and Erie Canal, which enters the river at this point. In the palmy days of the

canal the town of Independence was located here at the dam, but when the railroad superseded the canal the town moved elsewhere. The water above the dam backs for 7 miles up the Maumee and about 2 miles up the Tiffin and Auglaize Rivers and forms a charming lakelike body of water below Defiance. This water is navigable for small boats and launches, of which there were a considerable number. The river is some 600 feet wide at the dam, and at the time of our visit a thin sheet of water was pouring over. We had been informed while at Defiance that there were many fine mussels below the dam. (See fig. 4, pl. II.)

Examination of the place proved the accuracy of our informant and showed that this locality was the richest collecting ground and supported a greater variety and abundance of life than any other stretch of the river. The river bed below the dam is a broad valley with a limestone bottom, the river being broken up into a great number of pools and channels dotted with little islands overgrown with willows. The water, sparkling and fresh after its race over the dam, seemed to make conditions exceptionally favorable for all sorts of aquatic life. The shores of the pools were edged with water willows, and the stones on the bottom were covered with a rich growth of algæ of various species and hues, some growing in long ropy masses; there were especially large clumps of *Cladophora*, lending a green color to the bottom, and numerous larvæ of caddis and stoneflies gluing the pebbles together. Many crawfishes were seen, and Bryozoa were common on the rocks. There were many anglers in high boots wading about in the racing currents. Flocks of black tern were flying overhead, the first we had seen.

Fringing the edges of the pools and islands were many rather small shells, chiefly *Plagiola elegans* and young *Quadrula lachrymosa* that had apparently been killed by fishermen for bait. By feeling about in the sand in the shallow water shells could be found in great numbers, and they were of fine quality and very large size. The *L. ventricosus* were the largest we had seen. Everything considered, these are the most important mussel beds in the river, and this is one of the places worthy of future study.

It was at this place we found a couple of pearls, which, on account of their minute size, were of no market value. They were, however, of considerable interest, as, on account of their position, they served to intensify the suspicion already entertained that pearl formation may be excited by the presence of the marginal cyst. We are of the opinion that this is an exceptionally favorable location for the carrying on of investigations along this line.

At the Defiance Dam we entered by means of a lock into the first stretch of the canal, which runs from Defiance to Grand Rapids, Ohio.

The canal has a moderate current and is a picturesque waterway, with a winding towpath on one side and a country road on the other.

Station 17. Maumee River at Florida Bridge, Ohio.—This is 4 miles below the dam, and the river had very much the same character as at the previous station, except that there appeared to be more water than at the very foot of the dam. There was not a great deal of current, and the water was clearer than any we had yet seen; the mussels could be clearly distinguished in 18 inches of water. The bottom was still of flat rock, so that it was only in favorable places that the mussels could anchor. They were fairly abundant, but considerably smaller than at the dam.

Station 18. Miami and Erie Canal, near Texas, Ohio.—Near a small village named Texas considerable dredging was done in the canal. The uniformity of bottom and absence of rocks or snags made the dredging very easy. The bottom was of soft black mud and the water about 5 feet deep with a moderate current. We found here a scattered bed of *Quadrula undulata;* every dredge haul brought up a few examples. These were large and rather plump, with a black epidermis, and approached more nearly to the form of *Q. plicata* than the very compressed brownish examples we had been finding hitherto. These shells bore colonies of *Plumatella polymorpha.* Below Texas there are two tedious locks in the canal, after which we entered the broad expanse of the Maumee above Grand Rapids Dam. At the last lock we saw valves of *Q. lachrymosa.*

Station 19. Maumee River above the Grand Rapids Dam.—Here, as at Defiance, the dam backs up the water for several miles, and at this place the river is widened to 2,000 feet or more. Mussels were reported plentiful in this dead water and a few hauls with the dredge verified the correctness of the report. The water here is 18 feet in depth and the bottom is covered with mud in which are patches of sand and rocks, and it is very good dredging, being free from snags. Only three species were obtained, but they were all large, fine shells.

Station 20. Maumee River below the Grand Rapids Dam.—This dam, like the one at Defiance, was built by the State of Ohio as a feeder for the Miami and Erie Canal. It is 5 feet in height and a little over 1,800 feet in length and interrupted at the center by an island 350 feet in width, known as Purdys Island. At the time of our visit (Aug. 17) no water was running over the dam, all the surplus escaping by the canal on the north bank of the river and a mill race on the south bank. The river bed below the dam is broken up into numerous channels separated by islands covered with water willows and other plants much as it was below Independence Dam at Defiance. Here, however, the bottom is a fine-grained sandstone which has been largely quarried for building purposes, with the

result that the channels are broken by long deep ruts and numerous pools. The water was very clear and in the shallower portions of the pools the shells could be seen distinctly. In one of the pools especially the mussels, crowded together and interspersed with numerous crawfishes, showed up so clearly that they made a recognizable impression on a photographic plate through about a foot of water.

The mussels here evidently have a hard time finding enough soil to hold them in place, and many appear to be washed out and down the river during high water. Several were seen lying on their sides on the bare ledges. (See fig. 4, pl. II.)

There was some pearl excitement at Grand Rapids, but it appeared to be confined chiefly to boys. The mussels can be very easily obtained, and shells, cut open by the pearlers, were strewed in large numbers over the rocks about the edges of the pools. Several of the boys that we saw had vials of small irregular slugs or baroques to sell, but they contained nothing of any value. The inhabitants of the place told us that button men had been there prospecting for shells and had offered $40 per ton for a species which we judged from their description to be the black sand shell, *Lampsilis rectus*. The shells of that particular species were so uncommon, however, that nobody thought it worth while to hunt for them.

There was some fishing in the pools below the dam, and mussels, especially small *Quadrula pustulosa*, were used for bait.

Station 21. Miami and Erie Canal at Grand Rapids, Ohio.—At the end of the dam opposite Grand Rapids we entered into the second stretch of canal, which leads from Grand Rapids to Toledo, Ohio. At the very head of the canal we dredged and examined the shores for signs of mussels. We obtained only one *Anodonta grandis* on the dredge, and this was heavily infested with the sporocysts of the distomid of Osborn. A few dead *Plagiola elegans* and *Obliquaria reflexa* were found on shore, probably left there by a muskrat. The canal is a pleasant stretch of water without any obstructions, running parallel with the river. (See fig. 6, pl. II.)

Station 22. Miami and Erie Canal, 4 miles below Grand Rapids.—About 4 miles down the canal, where a long fringe of upland forest borders the canal opposite the towpath, we came upon half a bushel of shells at the end of a burrow occupied by a mink or muskrat. The shells were all small. The *P. donaciformis* were of fine color and unusually large size. The finding of this pile of shells was a fortunate circumstance, as it contained a good number of shells belonging to species which we could not find in any quantity and which are not readily obtained by the dredge. Indeed, considerable dredging in the canal opposite the shell pile yielded only *Q. undulata* and *Q. lachrymosa*.

Fig. 4.—The Maumee River below the State Dam, Defiance, Ohio, the richest collecting ground in the river.

Fig. 5.—The Auglaize River, 2 miles above Defiance, Ohio, showing the small islets and pools containing dense beds of mussels.

Fig. 6.—A stretch of the Miami and Erie Canal, an excellent breeding ground for mussels, and an ideal place for artificial propagation.

As a usual thing, the muskrat appears to feed on other material, chiefly vegetables, during the summer, beginning its mussel diet more extensively in the autumn, and the first mussels killed are usually small.

From this station on, piles of shells along the shore indicated molluscan life, which would otherwise have escaped notice, and also the presence of muskrats.

Station 23. Miami and Erie Canal, 8 miles below Grand Rapids, Ohio.—Here, opposite a farm belonging to Mr. Neifer, a few hauls were made with the dredge, and a single *Quadrula pustulosa* and 15 to 20 *Q. undulata* were obtained.

Station 24. Maumee River, 4 miles above Waterville, Ohio.—The river here is much wider than at Grand Rapids; there are broad riffles and the bottom is mostly of flat limestone. There are only a few patches of sand in the bottom among the numerous islands, which are covered with willows, water willows, etc. Shells were fairly plentiful where they could obtain a foothold. There are many dead shells on the islands and a few small *U. gibbosus* and *P. elegans* on shore freshly killed, probably by a muskrat.

Station 25. Miami and Erie Canal, opposite station 24.—Two dredge hauls were made in the canal opposite the last station on the river, but only a single example of *Anodonta grandis* was obtained.

Station 26. Miami and Erie Canal, 1 mile east of Waterville, Ohio.—Just below the bridge which crosses both the canal and the river, 1 mile east of Waterville, Ohio, two dredge hauls were made. The canal here was about 6 feet deep and the bottom was of a rather soft black mud. The *Q. undulata* were rather inflated, with black epidermis and well covered with the bryozoan *Plumatella*, like those taken near Texas, Ohio.

Station 27. Miami and Erie Canal at Westcott, Ohio.—At Westcott, Ohio, a small village above Miami, a few dredge hauls were made in the canal, but only one *Quadrula lachrymosa* and a few *Q. undulata* were obtained.

At Miami, which is only 7 miles from Toledo, the Maumee was wide, with but few islands, and deep enough to be navigable for launches, of which there were many in evidence. There were large patches of *Nelumbo lutea* scattered about in the river. The shore was examined for a considerable distance but no shells were found. During low water the riffles are said to extend from Grand Rapids to within a quarter of a mile of Miami; the shells, therefore, would probably be about the same for the entire distance.

Station 28. Miami and Erie Canal below Miami, Ohio.—About a mile below Miami a temporary dam had been thrown across the canal to allow the making of certain repairs in the locks below. This dam

stopped all the water except a small overflow stream which trickled along the very deepest part of the canal. At one place, where a small stream came rushing over a miniature cataract, a dense school of young fish, which appeared to be the skipjack, *Pomolobus chrysochloris*, were crowded together making frantic efforts to leap up the fall.

In the shallow water of the canal many mussels were found alive, while along the exposed portions of the canal bottom an opportunity was presented for studying mussel distribution similar to that in the feeder canal at Fort Wayne.

By far the larger part of the bed of the canal was open to observation, the central stream being very narrow. At one place the canal when full had overflowed at one side, forming a large lagoon or backwater, in which the water had been from 6 inches to a foot in depth. The bottom of this lagoon was nearly covered with dead shells.

It was noticeable that *Quadrula undulata* and *Q. pustulosa* withstand a scarcity of water better than most of the other species. There were more of these two species alive in the water than all the others together, and in several places on the exposed sides of the canal examples of one or the other of these two species were found with the flesh still adhering to the shells, showing that these mussels had withstood drying up longer than associated species. The little *Anodonta imbecillis* was found for the first time in considerable numbers at this place, both in the deeper and shallower parts of the canal. The conditions of the canal also gave an excellent opportunity to get very young shells of some of the smaller species, such as *Plagiola elegans* and *P. donaciformis*.

In connection with the last station on the river may be considered shells obtained on the beach of Put-in Bay Island in Lake Erie. These represent species of the lake into which the Maumee flows and from which that stream may have received some members of its mussel fauna. No live mussels could be obtained at Put-in Bay except a few occasionally washed up by waves. About a mile below the bathing beach a number of dead shells were obtained, representing the species given in the table.

In this list the words "common" and "few" refer only to the relative number of shells found. Considered as a whole, shells at Put-in Bay were rather rare, and all seen were much dwarfed.

Table Showing Distribution of Mussels in Maumee River.

[Note.—Abun.=abundant; Com.=common; numbers denote the actual number of specimens found.]

Mussel species.	Lettered stations.								Numbered stations.										
	A	B	C	D	E	F	G	H	1	2	3	4	5	6	7	8	9	10	11
Quadrula tuberculata (purple warty-back)	2	.....	.....	.....	Few.	.....	1	1	Few.	1	5	2	.....	.....	7	Few.	Com.	4	1
Quadrula coccinea	1	.....	.....	.....	Few.	.....	2	.....	.....	.....	7	1	.....	.....	Few.	.....	1	2	2
Quadrula rubiginosa	Com.	4	.....	Com.	Com.	Com.	16	15	Few.	Few.	107	2	2	.....	2	Few.	Few.	Few.	Few.
Quadrula pustulosa (pimple-back; warty-back)	.....	1	.....	.....	.....	.....	1	1	Few.	.....	45	2	1	.....	.....	.....	Few.	.....	.....
Quadrula cylindrica (rabbit's-foot)	1	.....	.....	.....	Few.	.....	.....	1	.....	.....	.....	.....	.....	.....	6	1	.....	.....	Few.
Quadrula undulata (three-ridge; blue-point)	Com.	9	.....	Com.	Abun.	Com.	11	78	Few.	Com.	7	2	.....	Few.	Few.	1	.....	2	1
Pleurobema clava	1	.....	.....	.....	.....	.....	.....	.....	Few.	Few.	.....	2	.....	.....	Abun.	Few.	Abun.	2	Com.
Unio gibbosus (spike)	Few.	.....	.....	.....	.....	.....	5	9	Few.	.....	.....	.....	.....	.....	Com.	.....	Few.	9	7
Alasmidonta truncata	.....	.....	.....	.....	Com.	.....	1	2	.....	.....	2	.....	1	.....	Few.	.....	Few.	.....	.....
Symphynota complanata (heel-splitter; hackle back)	.....	.....	.....	.....	Com.	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Symphynota costata (fluted-shell; squaw-foot)	Abun.	7	.....	.....	Com.	.....	13	86	Few.	2	22	22	6	.....	Com.	.....	Few.	1	.....
Symphynota compressa	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Anodontoides ferussacianus subcylindraceus	.....	.....	11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Anodonta grandis	.....	.....	.....	Com.	Com.	Com.	.....	9	.....	.....	.....	.....	.....	.....	.....	.....	Few.	.....	.....
Strophitus edentulus (squaw-foot)	1	1	.....	.....	Few.	.....	2	.....	.....	.....	1	.....	1	.....	.....	.....	.....	.....	.....
Ptychobranchus phaseolus	1	.....	.....	.....	Com.	.....	7	18	.....	.....	.....	2	.....	.....	.....	.....	2	Few.	7
Plagiola securis (butterfly)	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Obovaria circulus	Com.	.....	.....	.....	Com.	.....	2	2	Few.	1	5	1	5	.....	Few.	Few.	2	.....	Few.
Lampsilis gracilis (paper-shell)	.....	.....	.....	.....	.....	.....	.....	11	.....	.....	2	.....	.....	.....	.....	1	1	.....	1
Lampsilis alatus (pancake)	.....	.....	.....	.....	.....	.....	.....	5	Few.	.....	1	.....	1	.....	1	.....	.....	.....	.....
Lampsilis glans	.....	.....	.....	.....	Few.	Few.	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Lampsilis iris	Com.	.....	1	.....	Few.	.....	.....	2	.....	4	.....	1	.....	.....	Com.	.....	Few.	.....	Few.
Lampsilis rectus	1	18	.....	.....	Few.	.....	1	9	Few.	.....	6	2	7	.....	Few.	.....	2	.....	Few.
Lampsilis ligamentinus (mucket)	Com.	72	.....	.....	Com.	.....	36	60	Com.	Com.	24	71	4	Few.	Com.	Com.	Com.	Com.	23
Lampsilis luteolus (fat mucket)	Com.	14	.....	Com.	.....	Few.	11	22	Few.	.....	8	1	3	.....	.....	1	Few.	1	4
Lampsilis ventricosus (pocketbook)	.....	4	.....	.....	Few.	1	5	8	Few.	2	.....	12	2	Few.	Com.	Com.	.....	.....	1
Lampsilis multiradiatus	1	.....	.....	.....	Few.	.....	.....	1	.....	.....	.....	.....	.....	.....	1	.....	Few.	.....	.....
Micromya fabalis	.....	.....	.....	.....	Com	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Truncilla sulcata	Com.	.....	.....	.....	Few.	.....	.....	3	.....	Few.	1	1	.....	.....	Few.	.....	.....	.....	.....

Table Showing Distribution of Mussels in Maumee River.—Continued.

[Note.—Abun.=abundant; Com.=common; numbers denote the actual number of specimens found.]

Mussel species.	Numbered stations.																	Put-in Bay.	FF.
	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28		
Quadrula tuberculata (purple warty-back)			4		Few.	2			2									Few.	
Quadrula coccinea			2		Com.	Few.			Few.										
Quadrula rubiginosa			20	Com.	Com.				Few.				Few.				Few.	Few.	
Quadrula pustulosa (pimple-back; warty-back)			15	Few.	Com.	Few.			Com.		Few.	1	Few.		1		Com.		1
Quadrula lachrymosa (stranger; monkey-face)			3	3	Com.		Few.	Com.	Com.		Few.		1			1	Com.		
Quadrula undulata (three-ridge; blue-point)			37	Com.	Com.	Com.	Com.	Com.	Com.		Few.	20	Few.		9	Few.	Com.	Com.	
Unio gibbosus (spike)	1		8	Few.	Com.	Com.			Few.				Few.					Com.	6
Alasmidonta truncata			2			Few.													1
Symphynota costata (fluted-shell; squaw-foot)			7	Few.	Com.	Com.			Com.				Few.				Few.		
Anodonta grandis			1	Few.					Few.	1				1	2		Com.		
Anodonta imbecillis																	Com.		
Strophitus edentulus (squaw-foot)									Few.									Few.	2
Ptychobranchus phaseolus			5	Few.	2	Few.												{Few. (dwarf.}	
Obliquaria reflexa (warty-back)			1		Few.	Com.			Few.	Few.	Com.		Few.				Few.		
Plagiola donaciformis			1								Abun.						Abun.		
Plagiola elegans (deer-toe)			2		Com.	Com.			Few.	Few.	Com.		Few.				Com.		
Obovaria circulus			7															Com.	2
Lampsilis gracilis (paper-shell)			7	Few.	Few.				Com.								Com.	Com.	
Lampsilis alatus (pancake)	1	1	3	1	Few.	Com.		Few.	Com.				Few.				Com.	Com.	
Lampsilis iris																		Few.	
Lampsilis rectus			1	Few.	Few.	Com.			Few.									Com.	1
Lampsilis ligamentinus (mucket)		1	26	Abun.	Com.	Com.			Few.				Com.				Few.		
Lampsilis luteolus (fat mucket)	1		11	Few.		Com.			Com.									Com.	
Lampsilis ventricosus (pocketbook)		1	11	Few.					Com.									Com.	
Lampsilis multiradiatus						Few.													
Truncilla sulcata			1	1	Few.													Few.	

DISCUSSION OF MUSSEL SPECIES.

1. *Quadrula tuberculata* (Rafinesque). Purple warty-back. This is not a very common species of mussel in the Maumee or its tributaries, only a few occasional examples having been taken. It was most abundant in the upper portions of the river, near Fort Wayne, and down as far as Maumee Center Bridge. No living examples were obtained below Defiance, Ohio, and only a very few dead shells were picked up below here, the last one being obtained at Waterville, Ohio. All specimens seen were kept, and only about 52 were obtained in the Maumee system altogether. The range of this species is given by Simpson[a] as "Mississippi drainage generally; southern Michigan; San Saba County, central Texas." While it is in the main a Mississippi form, it is one of those species which occur occasionally within the St. Lawrence Basin, and although not usually a lake-dwelling species a few old valves were found along the shore of Put-in Bay, The Maumee examples show very little variation. Although most of them were rather small, some of the shells seen at the clammer's camp near Fort Wayne were quite large. The few mussels of this species obtained alive usually contained small baroques in the dorsal region.

This mussel is of no value for buttons on account of its color. In addition to being purple, the luster is usually dull. The epidermis, which is commonly brown, is somewhat tinged with green in examples from Maumee Center Bridge. In some places the distomid of Kelly, associated with dorsal baroques, is a common parasite. The examples found in the Maumee River, however, are comparatively free from this parasite.

2. *Quadrula coccinea* (Conrad). This species is not as common in the Maumee Basin as *Q. tuberculata*, only about 31 specimens having been obtained. It was more abundant in the upper course of the river, but dwindled out and finally disappeared; the greatest number (10) was obtained at Kern's Reservation, not far below Fort Wayne, and the last one was taken at Florida, Ohio, in the riffles below the bridge. It is a species common to both the Mississippi and the St. Lawrence drainage. The larger number of examples seen were white nacred, though a few were rosy.

The larger white-nacred specimens would make excellent button shells, classing with the pig-toes, though considerably thinner.

3. *Quadrula rubiginosa* (Lea). *Quadrula rubiginosa* is one of the most widely distributed of our fresh-water shells and occurs in a great variety of situations; it is found in lakes as well as in rivers. It is fairly common all along the Maumee and its tributaries (except the Tiffin, which was not thoroughly examined and in which few

[a] Proceedings U. S. National Museum, vol. XXII, p. 795.

shells of any species were found). It was very abundant in the feeder canal and in its reservoir. A number of shells of this species were also found on the shore of Put-in Bay Island, Lake Erie.

Although during the summer's collection we obtained material exhibiting considerable variation, all examples found within the Maumee Basin were fairly constant in form, though some were short and humped. This species very closely resembles *Quadrula coccinea*, the only apparent difference being in the prominence of the ridge on the posterior umbonal slope; hence some specimens are difficult to classify.

Young shells of this species exhibit faint rays which disappear with age. The specimens obtained in the reservoir differed from most of the others in having a very satiny epidermis. The greater number of the shells have a white nacre, although in some cases it is yellowish or rosy. None of our examples are as rosy, however, as *Q. coccinea* frequently becomes. The flesh of this species varies from salmon or orange to deep red, the richness of its color probably varying with the nearness to the breeding season and the abundance of ova present; these latter are of a bright carmine color. Some specimens were found becoming gravid and one nearly ripe in the feeder canal July 27. On account of its commonness not all of the shells seen were collected; however, we obtained 112 examples from the Maumee Basin.

What seemed a peculiarity in the action of this mussel was the habit of burying itself in the early summer. On a visit to the reservoir of the feeder canal on June 30, the mussels were all projecting far out of the mud and actively moving about, while on July 23, at the same place, they were buried quite deep, and hard to find. They were also deeply buried in the feeder canal pools about the same date.

A probable explanation of this peculiar action is that the reservoir was quite shallow and the water became warm. The water becomes low during drouths, and the mussels may have gone down into the mud in anticipation of the pool going dry.

This species is sometimes more or less affected with *Atax*, though not badly. Those found in the reservoir were more affected than others.

Although its small size is something of a disadvantage, this species would make a fair button shell. It has good luster, and its comparative flatness would permit its being worked up economically.

Though there are a number of river shells superior to it, it is one of the best if not the best button species that would thrive well in ponds. A considerable number were weighed and measured, and the largest, obtained at the Defiance Dam, was 88 millimeters high by 306 millimeters long, and the dry shell weighed 101 grams.

4. *Quadrula pustulosa* (Lea). Pimple-back; warty-back. *Quadrula pustulosa* is another of the widely distributed mussels common to both the Mississippi and St. Lawrence drainage systems; but, although thus widely distributed, it is somewhat choice of its habitat. It shows a distinct preference for more or less sandy or gravelly bars with a live current. It does not usually form beds, but is generally more or less mixed in with other species. It was found throughout the length of the river, but most abundantly in the central portion. A few examples, some of them of good size, were found at Fort Wayne, especially in the feeder canal. The greatest number taken at one place was at Kern's Reservation, where 46 were obtained in a shallow bottom of sandy gravel. All these examples, and, indeed, nearly all found in the Maumee until we reached the Auglaize River, were small, dwarfed shells; those found in the Auglaize River and near the dam at Grand Rapids were of considerably larger size. A few of the shells were almost devoid of pustulations, and one small smooth shell, much produced forward and rounded, bore considerable resemblance to *Obovaria retusa*. The two largest examples obtained were 85 millimeters long and weighed (dry shell) 145 grams.

This is one of the species commonly used in button making, and where it reaches large size is fairly well adapted to that purpose. In the Maumee, on account of both their small size and their fewness, they are not an important item. Most of the examples secured were retained and numbered in all 156 shells.

5. *Quadrula lachrymosa* (Lea). Stranger; monkey-face. This species was found only in the lower courses of the river; none were encountered above the Auglaize. In that stream three examples, the first seen, were secured. From this point they were occasionally met with all the way down the river, and in the canal. Thirteen specimens were taken below the Defiance or Independence Dam, and below the dam at Grand Rapids, Ohio, 24 were obtained. This is the greatest number for any locality. The largest one seen was obtained here; its length was 115 millimeters and its weight (dry shell) 221 grams. All examples seen were retained, the total number being 46.

This shell is used in button making, and ranks in this respect along with the three-ridges. The irregular sulcation of the valves, however, puts it to some disadvantages in cutting, so that while it is an interesting and well-marked shell, it does not possess enough favorable qualities from the commercial point of view to make it desirable for propagation.

6. *Quadrula cylindrica* (Say). Rabbit's-foot. This has been regarded as a species of the Mississippi drainage, belonging principally to the Ohio, Cumberland, and Tennessee River systems. Only a few examples were found and these were in the feeder canal and upper

parts of the Maumee. It is therefore probable that they represent the result of migrations by way of the Wabash and Erie Canal. One example was found in the St. Marys River and four in the Maumee in the vicinity of Antwerp, Ohio; a few dead valves were occasionally seen, but not more than two or three at the most. None were found below the point just mentioned. In the feeder canal, where conditions were particularly favorable for a study of the fauna, four examples were found, and two fine valves, not mates, were obtained in the mouth of the St. Joseph. The shells found in the feeder canal were of an elegant compressed form with numerous triangular tubercles on the anterior portion, and represent the subspecies *strigillatus* B. H. Wright, which is considerably more attractive than the type form. They are rather dark in color, with green triangles, as is usual, and fine capillary rays. One example contained two *Atax*. This attractive species is not well suited to button making on account of its form and the fact that the nacre is frequently diseased; hence it is practically unknown to the trade.

7. *Quadrula undulata* (Barnes). Three-ridge, blue-point. With the exception of *Lampsilis ligamentinus*, *Quadrula undulata* is the most abundant species of mussels in the Maumee Basin. All the undulate mussels found were referred to this species except those at Put-in Bay, Lake Erie. Notwithstanding the statement made in nearly all the literature at hand that "the two species[a] are perfectly distinct and there is no need of confusing them," many examples were found that were hard to place. Different authors do not agree perfectly as to the differences between these species and, generally speaking, the characteristics given are rather vaguely expressed, a fault not due to the carelessness of describers but to the nature of the case. All descriptions seem to agree in stating that the umbones are more inflated in *plicata*, but we find this feature as variable as any other. In the large collection of shells of the Bureau of Fisheries belonging to these two types we have many intermediate forms and several series exhibiting almost perfect transition from one species to the other.

This species, as we have it, is exceedingly variable, so much so that in looking over the entire summer's collection it was possible to give the locality of a number of shells simply from their appearance.

Q. undulata was found to be fairly common along the river where there were any shells at all, and on account of its abundance only a small proportion of the shells seen were retained. Fourteen were obtained at the riffles in the St. Marys, where it was fairly common. In the St. Joseph River at Robinson Park and in the feeder canal it was abundant and attained large size; 10 examples were obtained from the St. Joseph and 23 were taken of the large number seen in the feeder canal. It also throve in the reservoir of the feeder canal.

[a] *Q. undulata* and *Q. plicata*.

Very few were found in the upper Maumee. None were noted in the shell pile collected by the clammers near Fort Wayne and only 15 were obtained in the river above Defiance, Ohio. In the Auglaize River the species is quite abundant and 52 specimens were secured. It was fairly common in the Maumee below Defiance. Ten examples were secured at the Defiance Dam, 6 in the canal at Texas, and 16 near the dam at Grand Rapids. It was the most abundant shell in the canal below Grand Rapids.

From Defiance down the river and in the canal these shells were blacker and considerably more inflated than those above; the specimens found in the feeder canal at Fort Wayne were usually quite compressed and brownish in color, while those below Defiance were full and black, suggesting *Q. plicata*. These latter shells were usually overgrown with patches of the bryozoan *Plumatella polymorpha*.

This is one of the staple species used in button making, the nacre having a good luster and the shell being thick and heavy. The small end is beautifully iridescent and frequently of an attractive blue color.

This species, along with its relatives, is in good repute among pearl hunters. We found a few minute pearls and small rough baroques, but no more than in other shells. It is fairly free from parasites; a very few *Atax* were found. The nacre is frequently stained brown. As the species is hardy and thrives in a variety of conditions, especially in canals, it might be a good sort of propagate where better species would not thrive. The total number of examples obtained in the river was about 180.

In Lake Erie, at Put-in Bay, we found a dwarf species of shell, *Q. plicata hippopœa* (Lea), resembling this.

8. *Pleurobema clava* (Lamarck). Simpson[a] regards this as a shell of the Mississippi drainage and gives its range as "Ohio, Cumberland, and Tennessee River systems, reported from Iowa City, Iowa, St. Peters River, Minn., and from Nebraska." Call reports it from the St. Marys and from another stream in Indiana (St. Joseph) of St. Lawrence drainage. In the Maumee Basin it was nowhere abundant, but fairly well distributed along the upper course of the river. One was found above Bluffton Road Bridge, and in the St. Joseph River two dead shells were found, one quite large. Two shells were found in the Maumee near Fort Wayne, while at Maumee Center Bridge we obtained 12 moderate-sized specimens. At Antwerp two small shells were seen, and dead shells were still fairly common several miles below that place. None were seen as far down as Defiance, nor any below there, nor were any found in Lake Erie at Put-in Bay. The whole number of specimens obtained

[a] Synopsis of the Naiades, Proceedings U. S. National Museum, vol xxii, p. 746.

was 20. The Maumee specimens are brightly polished and can be distinguished by this feature from the rest of the summer's collection.

This is an exceedingly handsome shell, but of no commercial importance, as both its small size and peculiar form are disadvantageous. The nacre, though usually white, is occasionally of a beautiful warm pink.

9. *Unio gibbosus* (Barnes). Spike. *Unio gibbosus* was fairly common the whole length of the river. It is one of the species of wide distribution and considerable variability. Our specimens do not exhibit much variation, however. Most were of the solid, shortened, somewhat humped type. The long examples, which have procured for the species the name "spike," sometimes closely resemble *Lampsilis rectus*, from which they can be distinguished by the sculpture of the umbones and by the shape of the lateral teeth, while the short humped form is frequently almost indistinguishable from *Ptychobranchus phaseolus;* about the only way to tell them apart is by observing the color and texture of the epidermis, that of *U. gibbosus* usually being darker, and by the shape of the body cavity. One shell was found in the St. Marys, two in the St. Joseph near its mouth, and three in the Maumee near Fort Wayne. It was most abundant in the central portion of the river from Maumee Center Bridge to the bridge at Florida, Ohio, and was common in the Auglaize River. Lower down the Maumee it gradually disappeared, the last few shells having been seen at Grand Rapids, Ohio, below the dam. In all, 63 shells were obtained in the Maumee Basin. It appears to be one of the common shells in Lake Erie, 16 having been found on the shore of Put-in Bay Island. Both purple and white nacred forms were present. The greater number, about two-thirds, had white nacre, one had rosy nacre, one had purple nacre, white at the edges, and the others were intermediate between white and purple. Young examples showed delicate rays.

This species is of no commercial value, as even the white forms have the nacre quite dull. In some localities the distomid of Kelly, associated with dorsal baroques, is a common parasite, but they are not abundant in the Maumee.

10. *Alasmidonta truncata* (B. H. Wright). This is not an especially common shell in the Maumee Basin. According to Simpson[a] it is a Mississippi Valley species which has migrated into the upper parts of the St. Lawrence Basin. It is rather variable in form and is sometimes difficult to distinguish from *Strophitus edentulus*. It was found in the feeder canal and St. Joseph River at Fort Wayne. Occasional examples were encountered along the course of the river, as 2 at Kern Reservation, 1 at Maumee Center Bridge, 1 at Antwerp, Ohio. Three large ones were obtained in the Auglaize River

[a] Synopsis of the Naiades, Proceedings U. S. National Museum, vol. XXII, p. 671.

and three in the Maumee below the Independence Dam. The last example was found below the dam at Grand Rapids, Ohio. In all, 15 specimens were taken.

This shell is handsome and odd, brightly splashed with blue or green and greatly inflated. It is of no commercial importance on account of its thinness. The nacre is usually whitish, though frequently with a bluish tinge and occasionally a beautiful pink or rosy.

11. *Symphynota complanata* (Barnes). Heel-splitter; hackleback. This species is common about Fort Wayne, being especially abundant in the feeder canal, where it was one of the most conspicuous members of the mussel fauna. Of the great number seen in the feeder canal 18 fine examples were taken; 2 were secured in the reservoir of the feeder canal and 5 in the St. Joseph River near its mouth.

This species is evidently an overflow from the upper Wabash drainage. Only one specimen was obtained in the Maumee River and that was at the very head near Fort Wayne; one which had been found at New Haven, about 7 miles below Fort Wayne, had been kept and was shown as a curiosity.

This shell was formerly not much used in button making, as it is usually rather thin for that purpose. Its broad flat surface and fair luster, however, are greatly in its favor, and more buttons can be cut out of one of its valves than from any other species except the large *Quadrula heros*. It appears to breed abundantly and bring forth large numbers of young. Gills of examples obtained in the Little Wabash River near Fort Wayne, September 26, 1906, were full to bursting with glochidia, which are brownish and give the whole mass a distinct brown color.

The species appears to have bred successfully in the feeder canal, as there were a great many young shells there. It would probably not thrive well in ponds, though a healthy example was seen in the reservoir of the feeder canal. It is not found in lakes, but is frequent in small streams with rather muddy bottoms, and is somewhat similar to *Anodonta* in habits. It is frequently the host of *Atax*, and is one of the species especially susceptible to infection by the parasite *Aspidogaster conchicola*, which inhabits the pericardial cavity, without, however, doing much apparent harm.

As this species lives where there is rather little current and thrives on a muddy bottom, it would probably be a valuable subject for cultivation. Its abundance in the canal suggests that it would respond well to artificial conditions.

12. *Symphynota costata* (Rafinesque). Fluted-shell; squaw-foot. This mussel was fairly common in the Maumee River throughout most of its length. One example was found in the St. Marys River

above the Bluffton Road Bridge, and 11 were obtained at the riffles. In the feeder canal 2 examples were secured. It was probably not uncommon there, but on account of its general abundance no more were taken. From 1 to 3 were found at most of the stations on the Maumee, so that it would be unnecessary and tedious to give its occurrence in detail. It was common in the Auglaize, where 13 examples were secured, and abundant in the Maumee below the dam at Grand Rapids, Ohio, where we obtained 23. One was found in the canal just below Grand Rapids. Some of the examples are beautifully rayed. The nacre is usually of a peculiar and pleasing yellowish shade. On account of the usual thinness of the shell, however, the species is commercially unimportant, few or none being used in the button business. Altogether we obtained in the Maumee Basin 125 shells belonging to this species.

13. *Symphynota compressa* (Lea). In the Maumee Basin we found only one example of this widely distributed species. This was found in the St. Joseph River near its mouth. The species is rather small and thin, and of no commercial importance.

14. *Anodontoides ferussacianus subcylindraceus* (Lea). This subspecies was found in only one locality in the Maumee drainage, and there it was the only species found except one fragment of *Lampsilis iris*. This was in a small stream, Spy Run, which enters the St. Marys at Fort Wayne. In this stream seven examples were found, all small dead shells. This species is of no commercial importance on account of the thinness of the shell.

15. *Anodonta grandis* (Say). This species delights in a muddy bottom and a slow current. It was rather common in such places as the feeder canal and its reservoir, and a few large examples (dead shells) were found along the St. Joseph River near Robinson Park. It was found only occasionally in the rivers; 5 were obtained at the riffles of the St. Marys River; 10 were taken of many found in the feeder canal; 12 were collected in the reservoir of the feeder canal. We found 8 in the St. Joseph River near its mouth. In the Maumee it occurred rather sparingly, 1 example having been obtained at the Maumee Center Bridge, 10 in the Auglaize River, 1 in the Maumee below the dam at Defiance, 5 below the dam at Grand Rapids, and 2 in the canal below Waterville. A number were seen below the dam in the canal at Maumee. Only a few of the examples seen were collected; the total number taken was 51.

The specimens from the feeder canal were unusually thick, appearing as if a second nacreous layer had been deposited.

Of all the species of mussel encountered, *Anodonta* was the richest in parasites, harboring the greatest number of species, and (except in the case of some *Lampsilis alatus* obtained at Grand Rapids which

contained great numbers of *Atax*) the largest number of individual parasites.

Most of the shells obtained were more or less stained red interiorly. This stain, caused by a parasite, the distomid of Osborn, varied greatly in extent, beginning in the umbonal cavity and extending from that region in two diverging lines, one anteriorly and the other posteriorly, ventrad. The V-shaped area thus formed gradually fills in with red until the whole surface is involved. This process has been quite fully described by H. L. Osborn[a] and by H. M. Kelly.[b] The minute distomids, showing pink against the mantle, were present in numbers varying from a few to several hundred.

Occasionally mussels of this species were found in which the distomids mentioned above had not yet escaped from the sporocysts. The shells of such mussels frequently had the nacre raised in sharp pearly projections, and in some cases the sporocysts seemed to have been overgrown with the nacre of the shell.

In addition to the distomid of Osborn, *A. grandis* also usually has a number of *Aspidogaster conchicola* in the pericardial cavity, several individuals of *Cotylaspis insignis* in the axils of the inner gills, and one or more species of *Atax* among the gills; even leeches are frequently found within the shells. The leeches are no doubt parasitic, as is evidenced by the fact that where a pile of freshly cleaned shells killed by muskrats were found under water on another occasion (at Lake Maxinkuckee) the leeches almost covered the insides of the valves.

On account of the thinness of its shell, *Anodonta grandis*, and indeed all the species of this genus, are of no value commercially.

16. *Anodonta imbecillis* (Say). This species has not heretofore been reported from the Maumee Basin. It was only infrequently found; one specimen was obtained on the shore of the St. Marys River, at Fort Wayne. After this none were seen until at the very end of the investigation, in the canal at Maumee, Ohio, below the dam; at this place 38 examples were taken. Their abundance here indicates that they were probably abundant also throughout the length of the canal, but do not "bite" at the dredge hooks. As none were found in the bottom of the feeder canal, it is probable that they do not occur there. This is a very pretty species, but it is of no commercial value.

17. *Strophitus edentulus* (Say). Squaw-foot. This species is not common in the Maumee Basin. Examples were occasionally found in the St. Marys River at Fort Wayne, in the feeder canal, and in the St. Joseph and upper Maumee Rivers. One was obtained at Grand

[a] Zoological Bulletin, vol. I, no. 6, 1898.
[b] Bulletin Illinois State Laboratory Natural History, vol. v, p. 406, 1899.

Rapids, below the dam. None were seen in the Auglaize River, nor in the Maumee at Defiance. One shell was found on the shore of Put-in Bay, Lake Erie. In all, only 8 examples were obtained in the Maumee Basin. It is of no commercial importance.

18. *Ptychobranchus phaseolus* (Hildreth). This species was not abundant anywhere in the Maumee Basin, but was scattered all along the length of the river. In the autumn of 1907 a fair number were obtained in the feeder canal. We found 16 good specimens in the St. Joseph River at Fort Wayne, 2 in the Maumee near its head, and 2 or 3 at occasional stations along the river. It was fairly common in the river below Antwerp, Ohio, where 10 shells were obtained at one station. Nine examples were secured in the Auglaize River, 2 in the Maumee below the dam near Defiance, and 3 at the bridge at Florida, Ohio, and 2, the last seen, were taken below the dam at Grand Rapids, Ohio. The examples obtained in the Auglaize August 8 were beginning to become gravid. In all, 53 specimens were secured from the Maumee Basin. Shells of this species were fairly common on the shore of Put-in Bay, where it was small but beautiful in color, luster, and form. The outer gills of gravid examples are remarkable for their folded and plaited appearance; the gills look like nests from which insect larvæ, like "wigglers," are ready to emerge. The nacre of some of the young shells is of a beautiful faint pink, but that of all the large old shells was white.

This shell has not been used to any extent, if at all, probably on account of the scarcity of supply, and it is not known to the trade. Its flatness, nearly uniform thickness, and excellent luster would make it worthy of experimentation in the button business. It would probably rank with the "butterfly," *Plagiola securis*, in that respect The presence of a number of young shells in the feeder canal indicates that it might be easy to propagate in artificial channels.

19. *Obliquaria reflexa* (Rafinesque). Warty-back. This species was first encountered in the Auglaize River, where 1 example was secured. Below the Defiance Dam 3 were obtained; 1 was found at Florida Bridge, and 3 at Grand Rapids below the dam. In the stretch of canal below Grand Rapids it was apparently abundant. One was picked up on the shore at the very entrance of the canal and 22 in a pile left by a mink or muskrat along the side of the canal. A few were found in the canal below the dam at Maumee. This species, being quite thick and of good luster, is used to some extent commercially, but on account of its small size a shell yields only a few buttons.

20. *Plagiola donaciformis* (Lea). The first example of this species was obtained in the Auglaize River. No others were seen until we reached Grand Rapids, Ohio, where 1 was found in the Maumee below the dam. In the stretch of canal near Grand Rapids it ap-

peared to be fairly common; 10 shells were taken from a pile left by some predaceous animal, and of a large number seen in the canal below the dam at Maumee 14 were secured, some of them quite young and small.

This is one of the most beautiful of our fresh-water shells, and the markings are very attractive. It is too small to be of any importance commercially.

21. *Plagiola elegans* (Lea). Deer-toe. No examples of this species were seen until the Auglaize River was reached, where we found 10. It was fairly common in the river and canal below this point. Living mussels and shells of some recently killed were very common in the Maumee below the dam near Defiance.

Of many examples seen we obtained 17 shells here. Below the dam at Grand Rapids, Ohio, we secured 6 shells, and at the pile of shells near the canal bank, which has been frequently referred to, we obtained 49 shells of this species. Some were seen along the shore of the Maumee 4 miles above Waterville, and it was common in the canal below the dam at Miami.

This is one of the prettiest of our fresh-water bivalves, but it is too small to be used much for buttons, though the largest examples are sometimes utilized. By clammers it is called the "deer-toe." It is fairly constant in form, but varies considerably in color and markings, the ground color being sometimes yellowish and sometimes green. The rays are often broken up into V-shaped blotches. The total number of examples collected was 97.

22. *Plagiola securis* (Lea). Butterfly. Of this species only 1 example, a large coarse specimen closely resembling some of the shortened and flattened forms of *Lampsilis ligamentinus*, was secured. This is a species belonging to the Mississippi drainage, and it is one of the most valuable shells for buttons. The specimen was obtained at the clammer's camp near Fort Wayne and was from the upper part of the Maumee.

23. *Obovaria circulus* (Lea). There appears to be considerable confusion among authors regarding the three so-called species *Obovaria circulus*, *O. lens*, and *O. leibii*, and by some authorities the two last named are regarded as subspecies of the first. We obtained the small inflated *O. leibii* on the shore of Put-in Bay Island. In the Maumee we obtained flatter, larger shells, which are similar to those in the collection of the Bureau from the Ohio and Tennessee Rivers. This species (*circulus*) occurs occasionally throughout the length of the Maumee. Three examples were found in the St. Marys River at Fort Wayne. It was fairly common in the feeder canal, where 16 specimens were secured, and in the St. Joseph River near its mouth, where we obtained 10. Six examples were obtained at Kern Reservation, five at Maumee Center Bridge, and 14 in the

Auglaize River, in addition to occasional shells picked up here and there. The last one seen was at Grand Rapids below the dam. The whole number obtained in the Maumee Basin was 60. This species is frequently infested with the distomid of Kelly, and contains small dorsal baroques. Diseased shells with one or both valves roughened and yellow on the inside were quite common. The shell is usually too small to be of much use commercially, but it has a beautiful luster, which continues in dead shells when exposed to the weather longer than in any other species observed. The nacre is usually white, though in some instances it is pink or rosy.

24. *Lampsilis gracilis* (Barnes). *Lampsilis gracilis* is fairly common and well distributed in the Maumee Basin, but is nowhere particularly abundant. Seven examples were obtained at the riffles in the St. Marys River and three in the St. Joseph near its mouth. In the upper part of the Maumee River it is rather scarce; only 1 was taken near Fort Wayne, 1 at Maumee Center Bridge, and 1 below Antwerp, Ohio. In the Auglaize River it was fairly common; 13 were obtained there. In the Maumee below the dam near Defiance it was rather abundant, 19 being found at that place. It was also abundant at Grand Rapids below the dam; here 16 were secured, and 2 in the canal below Grand Rapids. It was quite common in the canal below the dam at Miami, Ohio, though none were collected there.

In all, 63 examples were secured, and 10 additional dwarfed specimens on the shore of Put-in Bay Island, where it was quite common. This is one of the most iridescent shells we have, the posterior portion shading into a fine rainbow blue and purple. It is of no commercial value, however, on account of the thinness of the shell, which usually cracks badly in drying.

25. *Lampsilis alatus* (Say). Pancake. This species is of occasional occurrence in the Maumee Basin, but not abundant. Along the upper parts of the basin they were rather rare. Three were obtained in the St. Joseph River at Fort Wayne, and 1, small, in the Maumee, not far below its source. In 1907 several examples were obtained in the Maumee near Fort Wayne. A few scattered specimens were found below Antwerp, Ohio, and 1 in the Tiffin River a half mile above its mouth. Three were taken in the Auglaize and 11 large ones below the dam near Defiance, where it was beginning to become common. Three were found at Florida Bridge. Below the dam at Grand Rapids, Ohio, it was one of the most common shells and great numbers that had been opened by pearlers were seen on the rocks. We secured 23 examples here. A few were found in the second stretch of canal and in the Maumee above Waterville, Ohio. It was common in the canal below the dam at Miami, Ohio. In all, 56 specimens were taken in the Maumee Basin. At

Put-in Bay Island, Lake Erie, 10 small dwarfed examples were found; it appears to be common there.

The Maumee Basin examples, especially those obtained in the upper course of the river, differ from the usual type of the upper Mississippi River specimens in being considerably thicker, shorter, and more inflated. *Aspidogaster conchicola* is a fairly common parasite in the pericardial cavity, and the examples seen at Grand Rapids were infested with *Atax* to a remarkable degree, some individuals harboring nearly a hundred of the mites apiece.

There is a great deal of variation in the color of the nacre of this species, from pink to rich coppery red. Some of the shells were beautifully iridescent. On account of its color and the thinness of the shell it is of no use for buttons.

In the upper Mississippi, where this species thrives in great numbers, it forms the bulk of the cull shells left on shore, and on beds devoted to commercial purposes would probably be regarded as a nuisance. Richly colored baroques, usually of small size, occasionally occur in this species.

26. *Lampsilis glans* (Lea). This small, inconspicuous species is very likely to be overlooked in collecting, and is probably more common and more generally distributed than reports would indicate. It inhabits both ponds and rivers. In the Maumee Basin only 6 examples were secured—4 in the feeder canal, 1 in the reservoir, and 1 in the St. Joseph River near its mouth. All were dead shells picked up on shore.

27. *Lampsilis iris* (Lea). This attractive little shell does not appear to be common in the Maumee Basin. Two examples were secured in the St. Marys River above Bluffton Bridge, 4 in the St. Joseph near the mouth, 2 in the feeder canal, and 1 at Maumee Center Bridge, making 7 in all. It is probably more common than collections would indicate, as it is frequently found in abundance late in the fall after muskrats have begun collecting, where it has been difficult to find in numbers before this. It seems to be one of the favorite articles of diet with the muskrat.

28. *Lampsilis rectus* (Lamarck). While not particularly abundant, this is a fairly common and well-distributed shell in the Maumee Basin. Its distribution is so general that it is unnecessary to give details. It was quite common in the riffles in the St. Marys, and present in the feeder canal, St. Joseph River, along the Maumee, and in the Auglaize. Nearly every example seen was kept. In all, 63 were taken in the Maumee Basin and 3 in Lake Erie at Put-in Bay. Only a few young were seen, and a few gravid ones were obtained. The young are more or less distinctly rayed; in the adult the epidermis is about uniformly black, but the rays are represented by fine

plaitings. The female shells are more or less inflated and produced postero-ventrally, so that the ventral outline is somewhat arched.

Generally speaking, the color of the nacre is variable in this species; in some localities many of the shells are pink or purple. The great majority of the shells in the Maumee Basin are white, though the cardinal teeth may be pinkish, pinkish-purple, or purple. *Cotylaspis* is a frequent, and *Atax* an occasional, parasite. In a number of examples the nacre near the cardinal teeth was black and diseased. *L. rectus* reaches quite a large size in this basin; the largest example was 172 millimeters long and the dry shell weighed 375 grams.

On account of its relative scarcity the value of this species as now occurring in the river would not amount to much. It is, however, the most valuable indigenous species so far as price per ton of shell is concerned. In luster it is not greatly inferior to *L. anodontoides*, the most valuable of the fresh-water mussels. Its elongate form makes it as well suited to the manufacture of knife handles as *L. anodontoides* and for pocket knives the purple or pink nacred shells would not be so objectionable as in the manufacture of buttons, so that the advantage the other species has lies chiefly in the attractive color of its skin. At Grand Rapids we were told that a price of $40 per ton was offered for these shells. As this species lives under widely different conditions, such as rivers, canals, and even lakes and ponds (though it is usually dwarfed in lakes), it would be one of the most, if not the most, promising species with which to attempt artificial propagation in the Maumee.

29. *Lampsilis ligamentinus* (Lamarck). Mucket. This is by all means the most common shell in the Maumee Basin, occurring so frequently in the river that it would be both needless and tedious to go into details. At Fort Wayne it was common in all three rivers—the St. Marys, St. Joseph, and the Maumee—and in the bed of the feeder canal. It formed the great mass of the 25 tons of shells collected by the clammers at the head of the Maumee. At Fort Wayne it reached its maximum development, and though not actually immense, it was quite large and heavy, as heavy indeed as could be worked up profitably. The shells decrease in size as we go down the river, so that those in the middle portion are of only medium size. Those in the Auglaize River were fairly large. Although *L. ligamentinus* was found at most of the points examined for the whole length of the river, it became scarcer and showed a tendency to disappear from the lower stretches. It was not common in the second stretch of canal, though a few were seen in the canal bed below the dam at the very end of the trip. Only a small portion of the great number seen were taken; however, we saved 282 examples. A number of the shells were measured and weighed, of which the largest was

145 millimeters long and weighed 467 grams. The nacre of all the shells was white.

L. ligamentinus, the mucket, while not the very best of button shells, is not greatly inferior to the best, and on account of its commonness and favorable shape and size is the most common species in commercial use. In the upper Mississippi it occasionally has to be discarded on account of its pink nacre, but this feature is wholly absent from Maumee shells. Perhaps 90 per cent of the shells of the Maumee Basin that possess commercial value are *L. ligamentinus*.

This species is rather free from parasites. A few *Atax* frequently occur, but *Cotylaspis*, *Aspidogaster*, and the other parasites found so frequently in the thin-shell mussels, are usually rare or absent here. Encysted distomids are fairly common, though hardly so common as in *L. ventricosus*. They are usually found about the edge of the mantle, though they may also be distributed throughout the body. The common form, designated in this report as the marginal-cyst distomid, is of especial interest in this species, as it is occasionally the cause of the formation of pearls.

This species was not usually found gravid until late in the season. At the beginning of the Maumee investigation, in June, only a few examples were gravid, but the greater number were barren. As we proceeded down the river, it was noticed that in the Auglaize River, August 8, the gills had begun to fill with glochidia and had a faint blackish edge. On a visit to the riffles of the St. Marys on September 27 a large number of the mussels were found to be gravid.

Lampsilis ligamentinus is one of the most easily propagated of fresh-water mussels, and where it produces a heavy shell and white nacre, as it does in the Maumee, is one of the most valuable species for propagation.

Although well-marked specimens of *L. ligamentinus* are easily distinguished from the following species, *L. luteolus*, one frequently finds shells which are difficult to identify, apparently standing somewhere between the two.

30. *Lampsilis luteolus* (Lamarck). Fat mucket. *Lampsilis luteolus* was found in about the same situations as *L. ligamentinus* but not in such abundance. Most of the examples seen were collected and the number of shells in our Maumee collection is 134. None of our specimens are of the variety *rosaceous*, which is a form belonging to the St. Lawrence drainage.

Unlike *L. ligamentinus*, this species is usually abundant in lakes, as well as being an inhabitant of rivers. It is indeed one of our characteristic lake shells. We obtained a number from Put-in Bay Island, Lake Erie, but they were rather small, as is usual with lake-dwelling individuals. The examples found in the St. Joseph River and the feeder canal were remarkably large and fine. This species

appeared, like many of the others, to become smaller as we proceeded downstream.

L. luteolus is subject to infection by the same parasites as those which attack *L. ligamentinus*, viz, *Atax* and occasionally *Cotylaspis*. One example obtained in the mouth of the St. Joseph River contained a number of *Bucephalus polymorphus*.

This shell has nacre of about the same quality as that of *L. ligamentinus*, but the shell is usually smaller, and has more lateral curvature, so that it can not be worked up so advantageously in making buttons. It is well adapted to the manufacture of fancy buckles, however.

31. *Lampsilis multiradictus* (Lea). This very attractive little mussel was not common in the Maumee Basin, and nearly all those found were dead shells, so nothing was learned concerning its habits. Only 9 examples were found, and these were in the upper two-thirds of the river basin, in the St. Marys, St. Joseph, and Maumee Rivers, and in the feeder canal. In 1907 a fair number were found in the feeder canal, and it had apparently thriven there to some extent. It is of no commercial importance. The species is a resident of lakes as well as rivers.

32. *Lampsilis ventricosus* (Barnes). Pocketbook. This shell, though not especially common, occurs rather frequently in the Maumee Basin. At the riffles of the St. Marys 7 large examples were found. Very fine examples were also obtained in the feeder canal. In the reservoir of the feeder canal a fine but small specimen was found, pretty closely resembling *L. capax*. In the mouth of the St. Joseph River 18 were secured. Occasional examples were obtained all the way down the Maumee; in the Auglaize 14 fine specimens were taken. The largest ones found were in the Maumee below the dam at Defiance, and it was also common below the dam at Grand Rapids, and 2 more were secured in the Maumee above Waterville, Ohio. Altogether 83 examples were obtained.

This shell also lives in lakes and 12 were obtained in Lake Erie at Put-in Bay, all dwarfed.

Although well-marked specimens of this species are easily recognized, it has many deviations from the typical form. Some closely approach *L. capax*, and we have seen shells from Lake Maxinkuckee which seem to lie between this species and *L. luteolus*. In other localities it appears to run into a species which in its typical form is known as *L. ovatus*. However, in the Maumee Basin it is well marked and fairly uniform.

L. ventricosus is used to some extent in the button business, but it is quite frequently too thin for this purpose.

In spawning season this is a very striking shell, the breeding mussel projecting long vividly colored flaps from the mantle and mov-

ing these with a spasmodic motion, while the animal lies on its back. The spawning season does not appear to be strictly confined to any particular season of the year, but spawning individuals can occasionally be found throughout the summer. One was observed in the St. Joseph River at Fort Wayne on July 20.

The principal parasites of *L. ventricosus* are *Ataxe*, usually few in number, the distomid of Kelly which is frequently present but never numerous, and the marginal-cyst distomid, which is occasionally present in great numbers in the margins of the mantle and throughout the body.

33. *Micromya fabalis* (Lea). This is the smallest and one of the most attractive of fresh-water mussels. It is rather rare in collections, on account of its small size being easily overlooked. It was exceedingly abundant in the Feeder Canal; in 1908 we obtained a half dozen examples, and in 1909, by going over the ground thoroughly in search of this particular species, several hundred were secured.

34. *Truncilla sulcata* (Lea). Scattered valves of this species were seen along the shore of the St. Marys and Maumee, and now and then whole shells. Shells and valves were found on the shore of the St. Marys above Bluffton Street Bridge, along the St. Joseph near its mouth, and in the Auglaize River. Only 1 living example was found, and this was in the Auglaize. In all only 15 shells were obtained.

Truncilla triquetra was not found in the Maumee Basin, but we picked up several vales on the shore of Put-in Bay Island.

GENERAL DISTRIBUTION OF SHELLS IN MAUMEE RIVER.

In general, as to distribution of mussels in the Maumee River, certain species were found to diminish in number or size, or both, in a downstream course.

Quadrula tuberculata diminishes in both number and size until in the lower part of the river only a few dead and rather small shells were obtained. Dwarfed specimens were also found at Put-in Bay.

Q. coccinea gradually diminishes and finally disappears at Grand Rapids, Ohio; it was found at Put-in Bay.

Q. rubiginosa greatly diminishes in numbers, but a few remain until the very last.

Q. cylindrica, sparingly present around Fort Wayne, was not found far below Antwerp, Ohio; no living specimens were obtained in the Maumee.

Pleurobema clava diminishes in numbers and disappears at Defiance, Ohio.

Symphynota complanata was common and large in the feeder canal and is occasional in the St. Joseph at Fort Wayne. One speci-

men was seen at New Haven, Ind. We ourselves found none in the Maumee, except at its very head.

Ptychobranchus phaseolus decreases in numbers and disappears at the very last near Miami, Ohio. Dwarf examples were found at Put-in Bay.

Obovaria circulus diminishes rapidly in numbers, and the last one was found in the Auglaize River at Defiance, Ohio.

Lampsilis multiradiatus, fairly well distributed in the upper part of the river, wholly disappeared at Defiance.

L. ligamentinus decreased in number more than in size, but diminished considerably even in size.

Truncilla sulcata, never very common, was not found below Defiance, Ohio.

The following species increase in number or size, or both, with the descent of the river:

Quadrula pustulosa increases both in number and size until it is fairly common below Grand Rapids, Ohio.

Q. lachrymosa first appears in the Auglaize a little above Defiance and becomes quite common in the lower part of the Maumee and in the canal.

Unio gibbosus increases both in size and number and becomes one of the most common forms in the lower part of the river.

Anodonta imbecillis appeared in considerable numbers at the very last, in the canal below the dam at Miami, Ohio.

Obliquaria reflexa first appeared in the Auglaize River, near Defiance, and became fairly common below there; the same may be said of *Plagiola donaciformis* and *Plagiola elegans*.

Lampsilis gracilis shows considerable increase both in numbers and size. The same may be said of *Lampsilis alatus*, of which very few were found at Fort Wayne, while it was abundant in the lower stretches of the river.

The following species are of about equal size and distribution throughout the entire length of the river:

Quadrula undulata was fairly common everywhere. It prefers a solid bottom overlaid with a thin stratum of rather soft mud, and wherever these conditions were encountered it was pretty sure to be found.

Symphynota costata was also fairly common everywhere; it increased somewhat in size as we descended the river, the examples found in the Auglaize being the largest obtained.

Anodonta grandis was nowhere abundant, but was found at nearly every station. It prefers a soft muddy bottom.

Lampsilis iris was rare everywhere, but was found all along the river.

L. rectus was nowhere found in abundance; the examples collected near Defiance were especially large and of fine quality.

L. ventricosus was nowhere abundant, but was found occasionally all along the river.

Of exceptionally rare shells, *Plagiola securis* was represented by only 1 specimen, obtained at the clammer's camp near Fort Wayne. In searching over the pile of shells found in the poultry yard referred to in the early part of this paper, it is believed that an example of *Unio crassidens* was seen, but as the shell does not appear in our collections its presence in the river can not be predicated with certainty.

In his paper on "The hydrographic basins of Indiana and their molluscan fauna,"[a] Dr. Call gives a list of 27 species of Unionidæ from the Maumee River; of these, 5 species, viz, *Quadrula heros*, *Alasmidonta calceola*, *Obovaria retusa*, *Obovaria ellipsis*, and *Lampsilis subrostratus*, were not seen by us.

FOOD OF THE MAUMEE MUSSELS.

The character of the food of mussels may be better appreciated after a short account of the method of feeding.

If one looks at a mussel in its natural position in the water one of the first things to attract the attention is two openings, one large and usually conspicuously fringed with elongate papillæ, the other smaller and fringed or not, according to the species. These openings project from the posterior or sharp end of the mussel which is directed upward from the bottom. The larger fringed opening is toward the ventral portion of the mussel and is an incomplete tube formed by portions of the mantle placed together. This is the inhalent opening, and here water is taken into the gill chambers by means of waving cilia which beset the gills, mantle, and other parts of the body bordering on the mantle chamber. The water thus brought in contains oxygen and food particles. The small cilia move the particles up to the anterior end of the body between the large labial palps or lips, which form a sort of funnel to the mouth. Here the food passes through the short gullet into the stomach, and thence into a long convoluted alimentary canal, which finally ends at the smaller of the two openings noted above, the exhalent aperture.

There are minute pores in the gills, and through these the water is forced by cilia into the exhalent aperture, from which it returns to the lake or stream in which the mussel lives. Large robust mussels are able to produce quite a strong current, but this is usually not visible in the rippling water where they naturally live. It can be best observed in large river mussels removed from their native stream

[a] Proceedings Indiana Academy of Sciences, 1896, pp. 248–257.

and placed in the calm shallow waters of a lake. It is probable that these mussels breathe extra heavily in the less highly oxygenated lake water. The current from the exhalent siphons boils up violently and is ejected intermittently at more or less regular intervals.

In many mussels there is no direct communication between the gill chamber into which the water, bearing solid particles, enters, and the suprabranchial chamber from which it is ejected through the exhalent aperture. Some mussels have the gills free above posteriorly, so that the two chambers have direct communication, and in these it is possible for the mussels to shunt solid particles directly from the gill chamber to the chamber above without passing through the alimentary canal. We have no evidence, however, that this is ever done. The mussel probably exercises little choice as to the nature of its food. The papillæ which fringe the edge of the inhalent orifice are supposed to be water-testing organs, and the mussel can close itself against foul water or against positively objectionable material. In the feeding mussel, as observed in the stream or lake, there is no appearance of nicety or fastidiousness as to the particles swept in; the wide open, immobile, and expressionless lips admit the general current and its diverse minute population with a catholic impartiality. The alimentary canal of the mussel is usually filled with a sort of impalpable or sometimes gritty mud, and mixed in with this are found scattered organisms of various sorts which serve as food.

The impalpable mud usually corresponds closely in color and general appearance with the bottom in which the mussels are found; in rivers with yellow clay bottoms it is yellowish; in dark, muddy bottoms it is dark. It consists of fine particles which have been held in suspension in the water. In turbid streams it consists of the material which gives the water its turbidity, in clear ponds with bottoms of fine mucky silt it is black, and in those still waters full of diffused minute algæ and flagellates, which are common in ponds and pools, it is predominantly organic and of a greenish cast. In the latter case it usually consists almost entirely of colonies of plankton-scum (water bloom) algæ, which are frequently inclosed in clear vacuolelike spaces.

The moderately long alimentary canal suggests that the ingested material contains a low amount of nutriment; observations also seem to indicate that the digestive powers of the mussel are slow and feeble. In mussels which had been kept for several days *Scenedesmus* was found as fresh and green as ever, and in one mussel obtained in the reservoir of the feeder canal green flagellates were still alive and active after having been at least 36 hours in the mussel. While in these instances it is possible that digestion was delayed by the capture of the mussel and placing in changed surroundings, there are other indi-

cations that digestion is normally slow and imperfect. In mussels taken from the beds, washed, and immediately examined, diatoms found at the posterior end of the alimentary canal are frequently alive and exceedingly active; they appear to be even more active than when taken from open water, and the form and color of the chromatophores are unchanged. It is possible that in these cases the mussel obtains some nutriment from the outer coating of the diatom and that the removal of this makes the latter especially active.

The organisms found in the alimentary canal of mussels vary considerably with the places in which the mussels live, but, so far as observed, do not differ much, if at all, among the various species. They consist of such planktonts as are small enough to be taken in and not active enough to resist the force of the inward current produced by the mussel. The largest and most active planktont taken to any extent was the entomostracan *Bosminia*. This was found with considerable frequency in lake-dwelling mussels, but as all seen were dead, and many were simply empty shells, it was not possible to ascertain whether the mussel had taken in the living animals or not. Actively moving flagellates are quite frequently ingested. In the gill chamber of some *Quadrula tuberculata*,[a] a species with an exceptionally large inhalent opening, we found such objects as *Chironomus* larvæ and one small mature dipterous insect.

There are several organisms which are likely to be found in mussels wherever taken. Species of *Scenedesmus* are almost invariably present, as is also *Navicula* along with other diatoms and species of *Pediastrum*, such as *P. pertusum* with great frequency, *P. boryanum* rather commonly, and *P. ehrenbergii*, which appears to be a rare species everywhere, only occasionally. The rotifer *Anuræa cochlearis* is also found frequently and under all sorts of conditions, in lakes, ponds, and rivers. The part usually found is the empty lorica. Another common object found in the alimentary tract of mussels is a club-shaped, several-celled, brown object, probably the spore of a fungus or lichen.

With the exception of those just mentioned the organisms found within mussels are very diverse, and the creatures seem to be quite omnivorous within the limits of what they can capture. Just as in any stream one finds various types of plankton aggregates from the extreme type of "potamoplankton" or characteristic river plankton of the mid-current, recognizable by the scarcity of water-bloom algæ, to well-developed types of "limnoplankton" or lake plankton in the quiet sloughs and bayous, so in these different portions of the stream one finds different sets of organisms in the mussels. In lakes full of diffused water-bloom algæ, the material which forms the mudlike matrix of the food in river mussels is to some extent replaced by the

[a] Not in the Maumee River, however, where few were examined.

water-bloom algæ. These may serve also as food. The stomach contents of such mussels, when placed in vials of preservative, differentiate into a lower stratum of black mud and an upper flocculent stratum of fairly pure algæ.

The mussel may be regarded as a sort of living filter, feeding upon the filtrate it separates from the water. It would be worth investigating to ascertain whether they arrest and destroy pathogenic bacteria and thus become efficient purifiers of water. They are valuable aids in plankton investigations, capturing many minute organisms which escape methods of collection ordinarily in use. Though at the outset it hardly looks as if they could cope with the problem, their capacity for ingesting water-bloom algæ (*Clathrocystis*, *Lyngbya*, etc.) suggests that it might be worth while to investigate their efficiency as reducers of plankton scum.

The water bloom, as is well known, frequently becomes a nuisance. It collects in noisome masses of scum along shores of otherwise attractive lakes and reservoirs. Its taste and odor renders the water of reservoirs undrinkable, and for a remedy of this condition the copper sulphate treatment has been devised. Its presence in large quantities along the shores of our most beautiful lakes renders them unattractive during the late summer season, and in many places brings the bathing season to an early close. Aside from the filthy appearance of the water, many persons claim to be actually poisoned by the water bloom, and there are instances on record of live stock being fatally poisoned by drinking water covered with plankton scum. In addition to this, the great amount of decaying material in the water is said to take up oxygen, making the lower strata uninhabitable for fish. It is possible that by planting large numbers of mussels, supplemented by planting egg masses of *Chironomus*, which appear to hatch easily and the larvæ of which eat the coarser algæ, that the plankton-scum nuisance can be greatly abated.

The stomach contents of mussels taken from the main current of the St. Marys, St. Joseph, and Maumee Rivers were rather noteworthy for their paucity of organic material. Through the large mass of muddy matrix filling the stomach were usually scattered a few *Scenedesmus*, various diatoms, and an occasional *Pediastrum* or *Cosmarium*. At the riffles small brown cystlike objects, which may have been a species of *Trachelomonas*, were quite common; with the exception of this the mussel contained very little. Among the organisms noted were *Scenedesmus caudatus*, *Cœlastrum microsporum*, *Pleurosigma*, several forms of *Navicula*, *Phacus longicaudus*, *Pediastrum baryanum*, *Gomphonema*, a sponge spicule, and an active *Euglena*-like organism. The stomach contents of mussels taken elsewhere along the river and in its tributaries, as in the Auglaize at Defiance and the Maumee at Grand Rapids, were not essentially dif-

ferent. One of the examples of *L. ligamentinus* taken in the Auglaize, however, contained many very minute cylindrical objects with rounded ends, which were probably bacteria.

The stomach contents of the mussels found in the reservoir of the feeder canal, a shallow pondlike body of water, bore considerable contrast to that of the river. This reservoir was well populated with small green monads and similar organisms, and during the last days of our observation became covered over with a green scum. It was "puddle plankton" rather than that which is characteristic of either lakes or rivers. The stomach contents of the mussels were greenish in mass, and were found to consist of various organisms, mostly green in color and actively moving.

The main mass consisted of small globular and thick celled, green or brownish flagellates, probably *Trachelomonas lagenella*. Among other organisms were species of *Phacus*, several species of *Scenedesmus*, *Pediastrum pertusum*, *Gomphonema*, several species of *Navicula*, a little *Botryococcus brauni*, *Anurwa cochlearis*, *Cosmarium*, small fragments of a *Conferva*-like alga two or three cells long, fragments of the test of *Ceratium hirundinella*, and the brown objects resembling fungus spores. There were numerous narrow curved objects which were probably loricas of *Trachelemonas*.

PARASITES OF THE MAUMEE MUSSELS.

During the progress of the Maumee River investigations the parasites encountered were noted and examples saved for further study.

Generally speaking, *Anodontas* and other thin-shelled mussels are more heavily parasitized than the species having thick shells, and parasites are more abundant in shallow, warm, and quiet pools than in rivers.

The mussels of the feeder canal reservoir were more heavily parasitized than those of the main streams. The following parasites were observed:

1. *Cotylaspis insignis* Leidy, a small organism, which to the naked eye resembles a pale leech. The body is trumpet shaped, and the ventral surface has a large ovate disk cut up by partitions. By this disk the animal adheres to its host, and it usually inhabits the axils of the inner gills. It was most common in *Anodonta grandis* and occurred occasionally in most other species of mussels examined. An example of *Lampsilis rectus* obtained at the riffles contained the surprisingly large number of 67 of these parasites. So far as could be ascertained, this parasite produces no marked physiological effect upon the host and appears to do no particular harm.

2. *Aspidogaster conchicola* Von Baer bears a close general resemblance to the above, but is considerably larger, and the adhering

disk, which is larger and more complicated, has been aptly compared to the sucking disk of *Remora*.

This parasite affects various species of mussels, but its favorite hosts are species of *Anodonta*, *Symphynota complanata*, and *Lampsilis alatus*, in which considerable numbers were found. It usually inhabits the pericardial cavity of the host, though when considerable numbers are present they may be found in other parts of the body.

The finding of a small elongate "hinge pearl" in a mussel affected by these parasites suggested that, under peculiar circumstances, the body of one of these creatures may form the nucleus of such a pearl, since the shape of the two is quite similar. This supposition, however, needs further investigation. *Aspidogaster* reproduces within the pericardial cavity of the host without any marked metamorphosis, and they are found of all sizes, the minute ones having the same form as the adults.[a]

3. *The marginal-cyst distomid.*—A distomid forming spherical cysts was fairly common, especially in *Lampsilis ligamentinus* and *L. ventricosus*, along the whole length of the river. A few of these parasites were also found in one *Quadrula undulata* and one *Symphynota costata*. It is probably the species discovered and briefly described by H. M. Kelly,[b] who noticed it in four examples of *L. ligamentinus*.

The cysts are usually found along the edge of the mantle, generally in the muscular portion below the pallial line. They are also frequently embedded in other parts of the body, such as the adductor muscles, and especially in the keel of the foot, where they are occasionally found in great numbers. There are indications that they prefer muscular tissue.

Cysts of various ages were frequently present side by side in the same mussels. The youngest cysts are translucent and refractive, faintly yellowish in color, and resemble minute pearls embedded in the edge of the mantle. As they grow older they form conspicuous black dots. One of the smaller cysts measured was 0.3 millimeter in diameter, and a large blackish opaque one was 0.9 millimeter.

Examined with a microscope the younger cysts appear as brick-red spheres, crossed and recrossed by irregular cracks like those of a dried mud flat. Upon carefully breaking open this crust a minute distomid is released, which slowly crawls about on the slide. One of the distomids thus released was colorless, 0.365 millimeter long and 0.21 millimeter wide at its widest portion. Viewed from above, it was pear shaped in outline, the anterior end being acute, the body gradually broadening behind and the posterior end being rounded. It had

[a] The development of this species is given by Huxley, Anatomy of Invertebrate Animals, p. 178.

[b] Bulletin Illinois State Laboratory of Natural History, vol. v, p. 406.

two suckers, an anterior one at the small anterior end and a ventral one, about the same size, placed far back near the swollen posterior end. The posterior part of the distomid contained a mass of black material, probably food.

As the cyst increases in age it becomes black and forms a conspicuous dot about the size of a pinhead in the tissue. It is found on examination that the cyst itself, which is surrounded by the black material, has not increased in size, and the wall retains its brick-red color. The appearances indicate that the black material, which is probably a product of excretion of the parasite, has been passed through the cyst wall.

In our alcoholic material the cysts, which appear as small black spots to the naked eye, show under the simple lens as minute orange globes, surrounded by a semitranslucent halo, the alcohol having apparently dissolved out the black material around the cyst wall.

The marginal-cyst distomid reminds one in its general appearance of *Diplostomum*, which is frequently found encysted in the skin of fishes, especially minnows, forming small black spots. In the fishes, however, the black color surrounding the cyst appears to be due to a deposit of pigment by the fish.

The effect of this parasite (the marginal-cyst distomid) upon the mussel appears to be quite various, according to the location of the cyst. In many cases, probably where the cysts are near the inner surface of the mantle, no effect whatever appears to be produced upon the shell. Under other cysts the shell is stained brown, and where the cysts are near the outer surface of the mantle the whole edge of the shell is blistered irregularly and stained a steel-blue color. Moreover, as the cysts increase in size they form firm nodules in the mantle and cause the shell to be built out around them, so that they leave pits in the nacre similar to those left by pearls.

In studying the collection of shells of *L. ligamentinus* at the Bureau of Fisheries, which contains perhaps 2,000 specimens of this species and is represented by shells from widely separate parts of the country, peculiar malformations of the shell were observed, which were probably caused by the parasite under discussion. Among these markings are pits near the margin of the shell, such as we have frequently observed in the living mussel underneath the cyst, and sometimes these contain small attached pearls. One of the most marked features is a tendency of the antero-ventral portion of the shell to cease growing outwardly and either become thickened or gape away from the middle line so that the mussel can not tightly close its shell in front. It appears that the presence of the cysts keeps the affected portion of the mantle in a constant state of contraction, thus preventing it from building the shell outward in the

normal fashion. In some of our alcoholic material this contraction and thickening of the mantle is quite markedly shown. The effect of this peculiar form of growth on the shell as a whole is to give it a somewhat more inflated and elongate appearance than is characteristic of the species. Shells of *L. ligamentinus* thus affected approach the contour of *L. luteolus*; and while close approximation of these two species is not rare in normal shells, some of the puzzling cases are probably *L. ligamentinus* which has been modified by this distomid.

In *L. ventricosus*, which is very susceptible to the attacks of this parasite, we frequently have gaping shells, and others which are markedly thickened. Some of these thickened shells closely resemble those of *L. ligamentinus*. The marginal-cyst distomid is of especial interest on account of its connection with pearl formation.

Suspicion that this distomid had some connection with the formation of pearls was aroused when the objects were first encountered, as their form and position was especially suggestive. This suspicion was intestified by frequently finding small round pearls in the mantle of mussels, closely associated with the cysts. Finally, on decalcifying and clearing in paraffin and xylol, preparatory to embedding, a portion of the mantle containing a small round free pearl surrounded by the cysts, a cyst could be clearly distinguished in the center of the pearl. Our material, which was preserved by simply dropping the mussels into strong alcohol, was not in good condition for histological purposes, so that we were unable to demonstrate the nature of the tissues surrounding the pearls.

Our studies indicate that the marginal-cyst distomid is widely distributed. We have found the cysts in alcoholic material collected in the Mississippi River, in *L. ligamentinus* collected by Freeland and Williams in the Illinois River in 1907, in *L. ventricosus* collected in the Yellow River, Ind., by ourselves in 1908, and in *L. ligamentinus* collected in the Ohio by Boepple in 1909. From the appearance of shells examined, we judge it to be common in the Minnesota River.

4. *The distomid of Osborn.*—Quite frequently during our mussel investigations we have found *Anodonta* affected with small white sporocysts, which covered the outside surface of the mantle next the nacre. The nacre of these mussels was often raised into a number of sharp pearly blisters, and in some cases small white areas, conforming with the size and shape of the sporocysts, indicate that the sporocysts had been actually covered with nacre. Mussels thus affected were found in the Little River ditch near Aboite Station, Ind., and in White Bear Lake and Lake Minnetonka, near St. Paul, Minn., in 1908. Notes on alcoholic examples of *Anodonta* collected in Wild Cat Creek, Carroll County, Ind., in 1899 refer to "white distomids," which were probably this species.

In the reservoir of the feeder canal at Fort Wayne we found an *Anodonta* plentifully infected with these sporocysts, and were able to make out in detail some of the steps in the life history of the animal.

The sporocysts were small white objects, elliptical in outline, about 1.14 millimeters in length and 0.05 millimeter wide. The skin of the sporocysts was transparent enough to reveal, in the interior, the cercariæ, which were three in number in most cases examined, closely doubled up and snugly packed together, and performing an uneasy wiggling motion. The walls of the sporocyst easily rupture; in an example studied at St. Paul the previous year the covering was torn apart by a dissecting needle and the cercarian set free. In the example now under discussion the sporocysts were rupturing of their own accord, allowing the cercariæ to escape. The following is a description of the various stages observed:

Cercaria just escaped from the sporocyst:

Body elongate cylindrical with bluntly rounded ends and divided by a well-defined constriction into an anterior two-thirds, the body proper, and a posterior one-third, the "tail." Body portion elliptical in outline with the two ends similar. Anterior sucker terminal, about one-fourth the greatest body diameter, circular, with concentric ridges faintly marked.

Posterior sucker one-third body diameter, also circular, but with radiating ridges, situated almost in the exact center longitudinally as well as transversely; constriction only one-seventh the body diameter with a well-defined groove all the way around. Posterior portion (tail) almost perfectly elliptical, twice as long as wide, both ends alike and more bluntly rounded than the body proper. Tail covered with a thick epidermis, raised into longitudinal ridges close together, very narrow and zigzag in arrangement.

The internal structure is indistinct, but far enough developed to distinguish the pharynx and digestive canals. The former is relatively smaller than in the adult and is much nearer the posterior sucker than the anterior one. This means that in after development the posterior sucker travels backward, while the pharynx travels forward. At this stage the whole interior of the body is filled with large cells having numerous and interlacing intercellular spaces.

After remaining under the cover glass for a little time the tails break off at the constriction and the body moves about alone.

The following is a description after the tail is shed:

Body elongate, ovate, without any traces of segmentation or separation into parts; anterior end evenly rounded, posterior end drawn out into a point, bluntly rounded at the tip.

Anterior sucker terminal, circular, three-sevenths the diameter of the body, with circular ridges. Posterior sucker on the mid line

of the ventral surface, four-sevenths of the entire length from the anterior end, circular, with radiating ridges and four-sevenths the diameter of the body. Posterior end of body with traces of the zigzag longitudinal ridges seen on the tail of the young. Mouth in the center of the anterior sucker, opening into a spherical or transversely elliptical pharynx close behind the sucker and one-third its diameter. From the pharynx two digestive tubes lead back to the posterior end of the body, one on each side, each a little narrower than the pharynx, of nearly uniform diameter throughout, and curved outward parallel to the lateral body margin. They reach nearly to the posterior end of the body, where each ends in a network of intercellular spaces and tubes, the excretory organ.

The newly escaped cercarium is about 1.05 millimeters in total length and 0.2 millimeter wide. The length and width are constantly changing, according as the organism is stretched out or contracted.

The tail is no longer an organ of locomotion; it is very large and unwieldy and easily detached; most of the cercaria shed it soon after emergence from the sporocyst, so that it is evidently a vestigial organ.

After shedding the tail the organism, which now has the typical form of a *Distomum*, moves up to the umbonal region of the mussel and acquires a pinkish color. From the umbones it spreads in diverging lines postero-ventrally and antero-ventrally and finally fills in the space between. Where it is located it profoundly affects the nacre, staining it a salmon color, and frequently giving it a diseased appearance. The presence of this distomid in *Anodonta* and its relation to the salmon-colored nacre was first pointed out by H. L. Osborn[a] and further discussed by H. M. Kelly.[b]

In its general appearance and in its life history this organism agrees very closely with *Distomum duplicatum* as described by von Baer, who gives a detailed description of the sporocyst and a history of the escape of the cercaria and its subsequent behavior.[c] It differs from that species in the fact that the tail is not clavate, is longer than the body, straight, and not pediculate. It differs from the cercarian genus *Rhopholocerca* Diesing, formed to include *D. duplicatum*, only in the fact that the tail is not clavate. Von Baer describes what appeared to him a form of reproduction in this distomid, but from what is now known of related forms it appears probable that he misinterpreted appearances. *Distomum duplicatum* (known also as *Rhopholocerca tardigrada* Diesing) is of special interest as the organism first shown by De Filippi to be the cause of pearls in

[a] Zoological Bulletin, vol. 1, no. 6, 1898.

[b] Bulletin Illinois State Laboratory Natural History, vol. v, art. viii.

[c] Nova Acta Physico-Medica Academiæ Cæsareæ Leopoldino-Carolinæ, Natural Curiosorum, vol. xiii, pt. 2, 1827.

Anodonta cygnea of Europe; hence a few remarks concerning it may not be out of place.

So far *D. duplicatum* has not been reported from any mussels except *Anodonta*. Its discoverer found it usually in the kidneys of *Anodonta ventricosa* and more rarely in the same organs in *A. anatina*. One badly infected example of this latter species had the sporocysts in the kidneys, gills, pericardial cavity, and edge of the mantle, and in an example of *A. ventricosa* they were even present in the general circulation. Filippi found the sporocysts and free distomids in the mantle of *A. cygnea*, some of them surrounded by nacre; and Pagenstecher found them in the tissue of the genital glands, liver, and kidneys of the same species. In this country Leidy[a] has reported "*Rhophalocerca tardigrada* attached to the mantle of *Anodonta fluviatilis;* specimens also obtained by Mr. Lea from *A. lacustris*."

The mature form of *Distomum duplicatum* is said to be *D. tereticolle* Rudolphi, a parasite of fresh-water fishes.

To return to the distomid of Osborn: In addition to its being found in *Anodonta grandis*, this parasite (in the distomid form) has also been reported from *Strophitus edentulus* by Osborn. We had very few living mussels of this species to examine; however, we found dead shells with the peculiar salmon-colored nacre, similar to that produced by this parasite in *Anodonta*.

In view of the fact that a *Distomum* quite similar in appearance to this is found in other species of mussels, while sporocysts are rare (we found them only in the liver tissue of one example of *Quadrula tuberculata* in Tippecanoe River), it becomes an interesting question whether this distomid migrates from the *Anodonta* to other mussels after issuing from the sporocyst. In the first place, such a migration is probably not an event closely connected with the life history of the species; for the tail, which functions as an organ of locomotion in those species which do migrate, has here been allowed to become functionless, or even a dead weight. Moreover, if the host of the mature form is a fish, as one might expect it to be from the life history of its near relative *D. duplicatum*, it would be to the advantage of the distomid to remain in the thin-shelled *Anodonta*, which is much more likely to fall a prey to fishes, or indeed any other predaceous animal, than the thicker-shelled species of mussels. It is very likely, however, that, just as in greatly infested mussels the cercariæ frequently overflow the organs which appear to be their favorite habitat, so a considerable number of distomids may be crowded out of the host mussel and be forced to seek protection and food elsewhere. According to von Baer[b] the sporocysts of *Distomum*

[a] Proceedings of the Academy Natural Sciences, Philadelphia, 1858, p. 110.

[b] Loc. cit.

duplicatum and their contained cercariæ live for a considerable time in the water when removed from the host. Migration would therefore be possible.

It has so happened that the *Anodontas* in which we found sporocysts were all taken in early and middle summer, in July or August; we found free distomids, however, as early as work in the field began, in June. It would require the study of infected regions throughout the year to ascertain whether the various phases in the life cycle of this distomid bear any relation to the seasons. Von Baer found his *Anodontas* affected by the sporocysts of *D. duplicatum* in late autumn.

5. *The distomid of Kelly.*—In several of the thicker-shelled species of mussels, such as *Lampsilis ventricosus*, *L. ligamentinus*, *Obovaria circulus*, and especially in *Quadrula tuberculata* and *Unio gibbosus*, one frequently encounters pink distomids bearing a close similarity to the distomid of Osborn mentioned above. Kelley,[a] who first described and discussed these distomids, was of the opinion that they are identical with those described by Osborn as affecting *Anodonta* and *Strophitus* and producing a discoloration of the nacre.

Indications pointing to the identity of these two distomids are, first, the fact that dorsal baroques are formed in *Anodonta* by the distomid of Osborn, and second, that the distomid of Kelly, in addition to forming baroques in *Obovaria circulus*, frequently causes the nacre to become rough and assume a yellowish color, approximating the salmon color of affected *Anodontas*.

In their typical form as they appear in the thick-shelled species of mussels, these distomids exhibit several minor points of difference from the distomid of Osborn. Practically they present so different a set of manifestations that in our field notes it was found necessary to separate them.

After considerable study and comparison we are inclined to think them the same, but in this discussion, since the point of view is ecological rather than taxonomic, it will conduce to clearness to refer to this manifestation of the species under a different name. Similarly, it is convenient and customary to speak of the cercaria of a distomid, the nauplius of a crustacean or the leptocephalus of an eel. The distomid of Kelly is usually found in much fewer numbers than that of Osborn, a fact which suggests that it may be erratic or a stray migrant, and so far we have not found it associated with sporocysts or cercariæ except in the single instance of *Quadrula tuberculata* referred to above. It is usually confined to the outer surface of the mantle near the cardinal or lateral teeth of the mussels affected, and it is frequently associated, as Kelly has pointed out, with irregular dorsal baroques or pearls. It does not produce a salmon-colored stain in the nacre of the mussel affected, and usually

[a] Bulletin Illinois State Laboratory Natural History, vol. v, art. 8.

produces no stain at all. The discolorations frequently found in the umbones of mussel shells can not all be attributed to it, since in one pond where such stains are very frequent, no distomids could be found. In general, it is a baroque former rather than a stain producer. In some localities it especially attacks *Unio gibbosus* and *Quadrula tuberculata*, and the host mussels are peculiarly prolific in baroques. Most of the dorsal baroques which the clammers save and sell to dealers in jewelry are probably formed through the activities of this parasite. The baroques are known among the clammers as "chicken feed" and usually bring about $2 per ounce on the ground. In many places this material is fairly common and is a source of revenue among the clammers.

It is probable that the distomids which stray into large heavy-shelled mollusks fall out of the normal course of their life history unless they again migrate to thinner-shelled species, for the thick-shelled mussels, after they have grown, are proof against fishes, musk-rats, or any other predaceous animals, and live to die a natural death, or in these recent times to fall a prey to the clammer. This gives the parasitic distomid no opportunity to enter into another host in the usual manner. Crawfishes eat mussels that have died; but so far as known the host of the mature distomid is always a vertebrate.

Moreover, on the supposition that the distomids found in the heavy-shelled mollusks are migrants from *Anodonta*, *Strophitus*, or other thin-shelled species, these mussels, which are regarded as valueless by the clammer and destroyed by the wholesale, are of importance as an intermediary in the formation of baroques and perhaps all distomid-formed pearls. Similarly, though in a somewhat different manner, the cockle, *Cardium*, acting as an intermediate host between a species of mussel-eating duck and the salt-water mussel *Mytilus*, brings about pearl formation in the latter species, as shown in the investigations by Jameson[a] of pearl formation in *Mytilus*.

6. *Bucephalus polymorphus* (von Baer).—During the Maumee investigations this species was encountered in only one instance, when an example of *Lampsilis luteolus*, obtained near the mouth of the St. Joseph River, was found to be affected. In investigations outside the Maumee Basin it was not infrequently met. According to Kelly, who has had considerable experience with mussel parasites, it is fairly common, though not so common as *Aspidogaster*, *Atax*, or *Conchopthirus*, and affects a large number of species of mussels.

Bucephalus polymorphus is of considerable economic significance, since it has been shown by von Baer and later by Kelly that this species (and, as Kelly has pointed out, some other distomids as well) frequently affects the generative tissue of the host mussel to such an

[a] Proceedings Zoological Society London, vol. 1, 1902, pt. 2, p. 140–166.

extent as to wholly obliterate it and render the mussel incapable of reproduction. In those mussels (*Lampsilis gracilis*, *L. luteolus*, etc.) in which there is a marked difference in the form of the shell of the two sexes, *Bucephalus*, by arresting sexual development at various periods of the mussel's life, stops also the development of the peculiar form of shell characteristic of the sex. Shells are thus left at various intermediate stages of sexual development, though they may attain full size, and this has doubtless led to considerable perplexity in identifying them, or even to the descriptions of new species. It may also be partly responsible for the large amount of synonymy found in the *Lampsilis ventricosus* group.

It can be readily inferred that the introduction of *Bucephalus*-infected mussels into places where breeding or breeding experiments are being carried on would be likely to produce disastrous results. In collecting mussels for propagating purposes, therefore, shells of indifferent contour as regards sexual peculiarities should be viewed with suspicion. In addition, examples should be dissected to detect signs of the presence or absence of the trematode.

The mature form of *Bucephalus polymorphus* is *Gasterostomum fimbriatum* von Siebold, which is a parasite of the pike (*Esox*) and perch (*Perca*), and an intermediate host (eaten by the final host) is some species of minnow. (*Leuciscus* is one of the known hosts.) In ponds devoted to the breeding of mussels the ravages of *Bucephalus* might be held in check by avoiding the peculiar combination of mussel, minnow, and pike or perch, provided of course these were not the particular species of fishes required to carry the glochidia.

7. *Ascaris*-like worms were occasionally found in the alimentary canals of mussels, and are probably to be regarded as parasites.

8. Leeches were found quite frequently on the inside of the shells of *Anodonta*, in all probability genuine parasites. They appear to be quite fond of the mucus of mussels, as is shown by the following observation: On the inside of a number of valves cleaned by muskrats and left on the bottom in Lake Maxinkuckee, the leeches were found to have accumulated in considerable numbers. Leeches also frequently attack other species of mollusks, as *Planorbis*, in large numbers. It could not be ascertained whether they injured the mussels to any marked extent or not.

9. *Atax ypsilophorus* was a common parasite of mussels throughout the length of the river, and was particularly common on *Anodonta* in the reservoir of the feeder canal. An example of *Atax*, probably this species, found in a mussel at the riffles of the St. Marys River, was so heavily burdened with a growth of *Vorticella* on its body that it could hardly move about. We came across several other specimens similarly affected.

Atax intermedius and *Atax tumidus* were also common on the mussels in the reservoir. There were probably several other species of *Atax* present; a small species with a red spot posteriorly was quite common. *Lampsilis alatus* below the dam at Grand Rapids was particularly heavily infected; in three examples 290 mites were found, thus averaging about 97 per individual.

Many of the *Atax* were full of eggs, and eggs and larvæ in different stages of development were common but not markedly abundant on the inner side of the mantle and in the gills of the mussels. We did not observe this year what was so conspicuous a feature in 1907 of the mussels found in the lakes about St. Paul, Minn., at the same season of the year, viz, the young mites clustered thickly about the papillæ of the inhalent siphons. The mites were apparently not breeding as heavily in the Maumee, and the young were not so far advanced in development at the date examined. *Atax* probably produces considerable irritation in the mussel, but we have no evidence that it affects shell characters. Where they bury their eggs in the tissue of the mussel they leave small but conspicuous scars which are apparently permanent.

Although it has been suggested that the eggs of *Atax* may lead to the formation of pearls, we have been unable so far to find convincing evidence on this point. In our studies of mussels of the Wabash Basin we obtained a great number of calcosphæric structures, many of them in situations that suggest a close relation to *Atax* eggs. This subject is reserved for future investigation, as it does not pertain to Maumee studies and would lead too far afield.

Wherever we have examined mussels we have encountered the parasite *Conchopthirus*, a protozoan bearing considerable superficial resemblance to *Paramœcium*. This organism is of such universal occurrence that we have not taken trouble to specifically mention its presence. There are several species (*curtus*, *anodontæ*, etc.) parasitic on fresh-water mussels.

GENERAL CONCLUSIONS.

The Maumee River, as it exists to-day, is not on the whole a stream where clamming operations could be carried on profitably, as it would very quickly become exhausted if such operations were undertaken on a large scale. The mussels were apparently once much more numerous than at present. There are two conditions which militate against the well-being of mussels in the upper part of the river: The large amount of sewage, especially refuse from the gas works, and the irregularity of flow of the river, which has been increased by the removal of much of the original forest along the river banks. The best mussel beds in the river are at Fort Wayne, Ind., and below the dam at Defiance, Ohio. By far the greater number

of marketable shells in the river are *Lampsilis ligamentinus*, and the most valuable native species is *L. rectus*.

The species of mussels to be recommended for propagation naturally varies with different rivers. In the Maumee, the species generally regarded as the best button shell, the niggerhead, *Quadrula ebena*, could not be recommended as it is doubtful whether it would thrive in the shallow water. On the other hand, the mucket, *Lampsilis ligamentinus*, in many waters a poor or indifferent shell, is here remarkably large and thick, with nacre of an excellent luster, and is the best button species found in the river. This should be planted extensively as the main crop. *Plagiola securis*, the butterfly, would probably thrive in the water below Defiance Dam, and *Symphynota costata* would be well worth trying, especially in canals with black muddy bottoms, as it would be nearly certain to attain to unusual size and thickness there, and might rank as a good button shell.

The status of *L. rectus* is peculiar. In many streams and rivers this species is valueless on account of small size or purple nacre or both; in the Maumee it has large size and white nacre and is the most valuable species per pound native to the river. With enough button shells in the river to bring this species to the market it would be desirable to plant rather heavily of it. It would make a good export shell and yield the clammer much more revenue for work done and material handled than the button species.

The most valuable of the fresh-water mussels, *Lampsilis anodontoides*, would be well worth a trial. It is not native to the river, but there is every reason to believe that, like its close relative *L. rectus*, it would grow and thrive considerably better even than in rivers where it is native. Good shells of this species bring an unusually high price on the market.

As regards mussel parasites, the river appears to have about the average number as compared with other streams examined. They are usually most abundant in thin-shelled species in quiet waters. As regards pearls and pearly growths, which are closely related to parasites, these are few. The distomid of Kelly and dorsal baroques are rare. Round pearls, all very small, were occasionally found, and all these appear to owe their origin to the marginal-cyst distomid, which is quite common.[a]

[a] Since this was written, we have found several minute pearls which were formed about eggs of *Atax*.

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